15. East

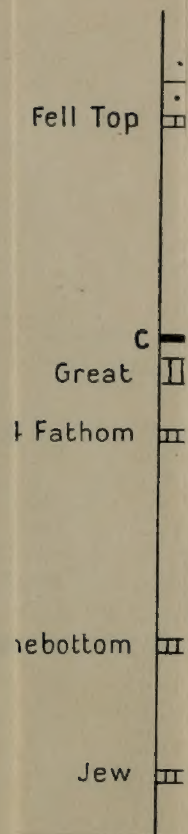
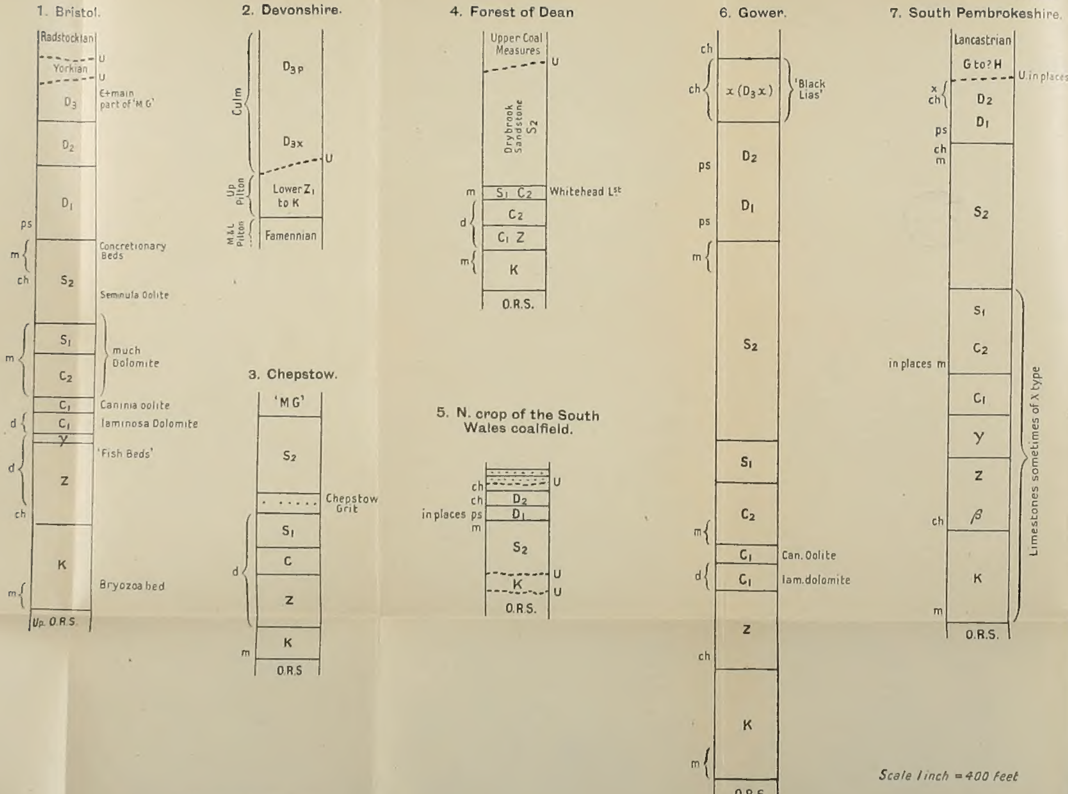
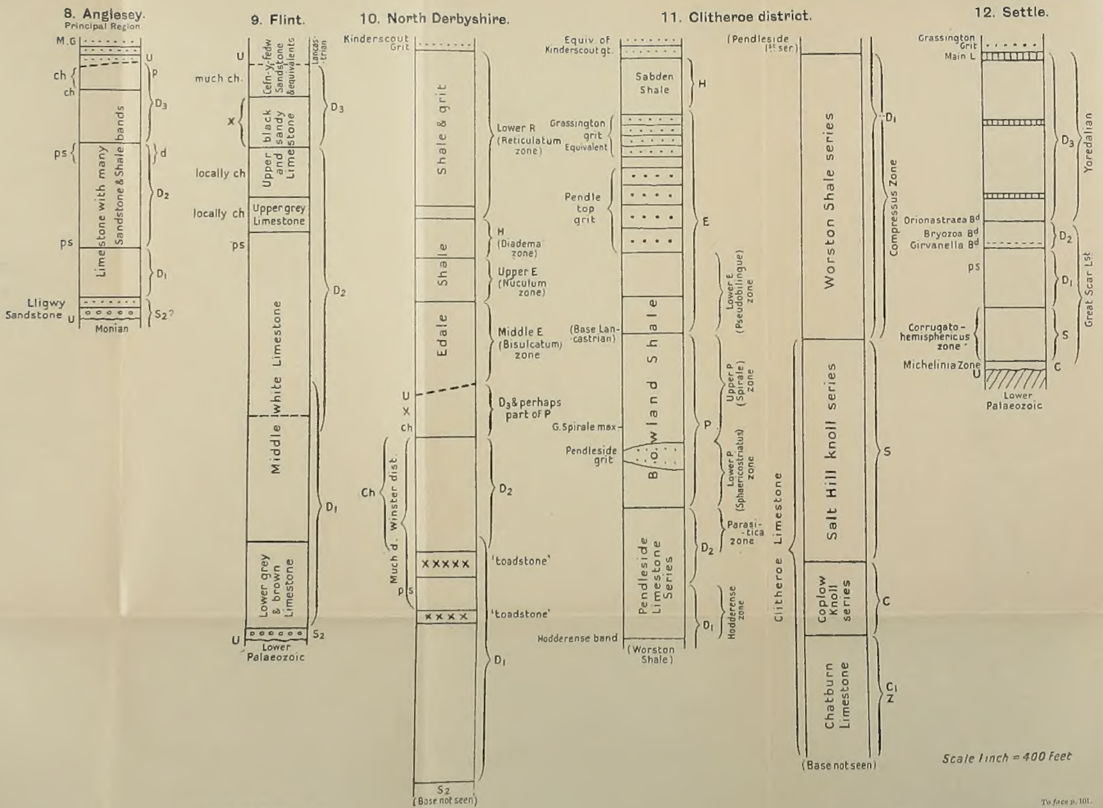


TABLE I.



Illustrating Prof. Reynolds' Address.

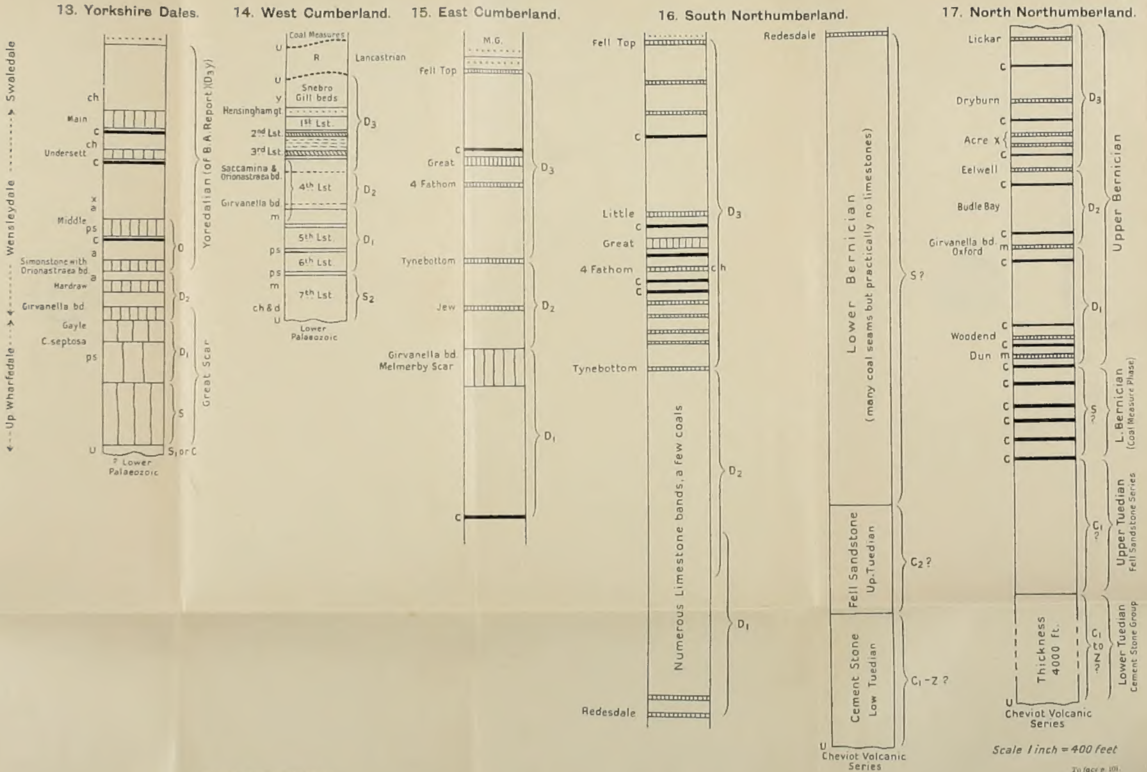
TABLE II.



Illustrating Prof. Reynolds' Address.

To face p. 101.

TABLE III.



Scale 1 inch = 400 feet

Illustrating Prof. Reynolds' Address.

To face p. 101.

BRITISH ASSOCIATION
FOR THE ADVANCEMENT OF SCIENCE

REPORT

OF THE

NINETY-FOURTH MEETING

(NINETY-SIXTH YEAR)

OXFORD—1926

AUGUST 4–11

LONDON

OFFICE OF THE BRITISH ASSOCIATION
BURLINGTON HOUSE, LONDON, W.1

1926

CONTENTS.

British Association for the Advancement of Science.

OFFICERS & COUNCIL, 1926-27.

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TABLE OF

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27	York	Viscount Milton, D.C.L., F.R.S.	—	—
1832, June 19	Oxford	The Rev. W. Buckland, F.R.S.	—	—
1833, June 25	Cambridge	The Rev. A. Sedgwick, F.R.S.	—	—
1834, Sept. 8	Edinburgh	Sir T. M. Brisbane, D.C.L., F.R.S.	—	—
1835, Aug. 10	Dublin	The Rev. Provost Lloyd, LL.D., F.R.S.	—	—
1836, Aug. 22	Bristol	The Marquis of Lansdowne, F.R.S.	—	—
1837, Sept. 11	Liverpool	The Earl of Burlington, F.R.S.	—	—
1838, Aug. 10	Newcastle-on-Tyne	The Duke of Northumberland, F.R.S.	—	—
1839, Aug. 26	Birmingham	The Rev. W. Vernon Harcourt, F.R.S.	—	—
1840, Sept. 17	Glasgow	The Marquis of Breadalbane, F.R.S.	—	—
1841, July 20	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23	Manchester	The Lord Francis Egerton, F.G.S.	303	169
1843, Aug. 17	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26	York	The Rev. G. Peacock, D.D., F.R.S.	226	150
1845, June 19	Cambridge	Sir John F. W. Herschel, Bart., F.R.S.	313	36
1846, Sept. 10	Southampton	Sir Roderick I. Murchison, Bart., F.R.S.	241	10
1847, June 23	Oxford	Sir Robert H. Inglis, Bart., F.R.S.	314	18
1848, Aug. 9	Swansea	The Marquis of Northampton, Pres. R.S.	149	3
1849, Sept. 12	Birmingham	The Rev. T. R. Robinson, D.D., F.R.S.	227	12
1850, July 21	Edinburgh	Sir David Brewster, K.H., F.R.S.	235	9
1851, July 2	Ipswich	G. B. Airy, Astronomer Royal, F.R.S.	172	8
1852, Sept. 1	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12	Glasgow	The Duke of Argyll, F.R.S.	194	33
1856, Aug. 6	Cheltenham	Prof. C. G. B. Daubeny, M.D., F.R.S.	182	14
1857, Aug. 26	Dublin	The Rev. H. Lloyd, D.D., F.R.S.	236	15
1858, Sept. 22	Leeds	Richard Owen, M.D., D.C.L., F.R.S.	222	42
1859, Sept. 14	Aberdeen	H.R.H. The Prince Consort	184	27
1860, June 27	Oxford	The Lord Wrottesley, M.A., F.R.S.	286	21
1861, Sept. 4	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1	Cambridge	The Rev. Professor Willis, M.A., F.R.S.	239	15
1863, Aug. 26	Newcastle-on-Tyne	Sir William G. Armstrong, C.B., F.R.S.	203	36
1864, Sept. 13	Bath	Sir Charles Lyell, Bart., M.A., F.R.S.	287	40
1865, Sept. 6	Birmingham	Prof. J. Phillips, M.A., LL.D., F.R.S.	292	44
1866, Aug. 22	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4	Dundee	The Duke of Buccleuch, K.C.B., F.R.S.	167	25
1868, Aug. 19	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18	Exeter	Prof. G. G. Stokes, D.C.L., F.R.S.	204	21
1870, Sept. 14	Liverpool	Prof. T. H. Huxley, LL.D., F.R.S.	314	39
1871, Aug. 2	Edinburgh	Prof. Sir W. Thomson, LL.D., F.R.S.	246	28
1872, Aug. 14	Brighton	Dr. W. B. Carpenter, F.R.S.	245	36
1873, Sept. 17	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25	Bristol	Sir John Hawkshaw, F.R.S.	239	36
1876, Sept. 6	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25	Swansea	A. C. Ramsay, LL.D., F.R.S.	144	11
1881, Aug. 31	York	Sir John Lubbock, Bart., F.R.S.	272	28
1882, Aug. 23	Southampton	Dr. C. W. Siemens, F.R.S.	178	17
1883, Sept. 19	Southport	Prof. A. Cayley, D.C.L., F.R.S.	203	60
1884, Aug. 27	Montreal	Prof. Lord Rayleigh, F.R.S.	235	20
1885, Sept. 9	Aberdeen	Sir Lyon Playfair, K.C.B., F.R.S.	225	18
1886, Sept. 1	Birmingham	Sir J. W. Dawson, C.M.G., F.R.S.	314	25
1887, Aug. 31	Manchester	Sir H. E. Roscoe, D.C.L., F.R.S.	428	86
1888, Sept. 5	Bath	Sir F. J. Bramwell, F.R.S.	266	36
1889, Sept. 11	Newcastle-on-Tyne	Prof. W. H. Flower, C.B., F.R.S.	277	20
1890, Sept. 3	Leeds	Sir F. A. Abel, C.B., F.R.S.	259	21
1891, Aug. 19	Cardiff	Dr. W. Huggins, F.R.S.	189	24
1892, Aug. 3	Edinburgh	Sir A. Geikie, LL.D., F.R.S.	280	14
1893, Sept. 13	Nottingham	Prof. J. S. Burdon Sanderson, F.R.S.	201	17
1894, Aug. 8	Oxford	The Marquis of Salisbury, K.G., F.R.S.	327	21
1895, Sept. 11	Ipswich	Sir Douglas Galton, K.C.B., F.R.S.	214	13
1896, Sept. 16	Liverpool	Sir Joseph Lister, Bart., Pres. R.S.	330	31
1897, Aug. 18	Toronto	Sir John Evans, K.C.B., F.R.S.	120	8
1898, Sept 7	Bristol	Sir W. Crookes, F.R.S.	281	19
1899, Sept. 13	Dover	Sir Michael Foster, K.C.B., Sec.R.S.	296	20

* Ladies were not admitted by purchased tickets until 1843. † Tickets of Admission to Sections only.

[*Continued on p.* xii.

ANNUAL MEETINGS.

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received for Tickets	Sums paid on account of Grants for Scientific Purposes	Year
—	—	—	—	—	353	—	—	1831
—	—	—	—	—	—	—	—	1832
—	—	—	—	—	900	—	—	1833
—	—	—	—	—	1298	—	£20 0 0	1834
—	—	—	—	—	—	—	167 0 0	1835
—	—	—	—	—	1350	—	435 0 0	1836
—	—	—	—	—	1840	—	922 12 6	1837
—	—	—	1100*	—	2400	—	932 2 2	1838
—	—	—	—	34	1438	—	1595 11 0	1839
—	—	—	—	40	1353	—	1546 16 4	1840
46	317	—	60*	—	891	—	1235 10 11	1841
75	376	33†	331*	28	1315	—	1449 17 8	1842
71	185	—	160	—	—	—	1565 10 2	1843
45	190	9†	260	—	—	—	981 12 8	1844
94	22	407	172	35	1079	—	831 9 9	1845
65	39	270	196	36	857	—	685 16 0	1846
197	40	495	203	53	1320	—	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 8 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883
317	219	826	74	26 & 60 H.§	1777	1855 0 0	1173 4 0	1884
332	122	1053	447	6	2203	2256 0 0	1385 0 0	1885
428	179	1067	429	11	2453	2532 0 0	995 0 6	1886
510	244	1985	493	92	3838	4336 0 0	1186 18 0	1887
399	100	639	509	12	1984	2107 0 0	1511 0 5	1888
412	113	1024	579	21	2437	2441 0 0	1417 0 11	1889
368	92	680	334	12	1775	1776 0 0	789 16 8	1890
341	152	672	107	35	1497	1664 0 0	1029 10 0	1891
413	141	733	439	50	2070	2007 0 0	864 10 0	1892
328	57	773	268	17	1661	1653 0 0	907 15 6	1893
435	69	941	451	77	2321	2175 0 0	583 15 6	1894
290	31	493	261	22	1324	1236 0 0	977 15 5	1895
383	139	1384	873	41	3181	3228 0 0	1104 6 1	1896
286	125	682	100	41	1362	1398 0 0	1059 10 8	1897
327	96	1051	639	33	2446	2399 0 0	1212 0 0	1898
324	68	548	120	27	1403	1328 0 0	1430 14 2	1899

‡ Including Ladies. § Fellows of the American Association were admitted as Hon. Members for this Meeting.

[*Continued on p.* xiii.

Table of

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1900, Sept. 5	Bradford	Sir William Turner, D.C.L., F.R.S.	267	13
1901, Sept. 11	Glasgow	Prof. A. W. Rücker, D.Sc., Sec.R.S.	310	37
1902, Sept. 10	Belfast	Prof. J. Dewar, LL.D., F.R.S.	243	21
1903, Sept. 9	Southport	Sir Norman Lockyer, K.C.B., F.R.S.	250	21
1904, Aug. 17	Cambridge	Rt. Hon. A. J. Balfour, M.P., F.R.S.	419	32
1905, Aug. 15	South Africa	Prof. G. H. Darwin, LL.D., F.R.S.	115	40
1906, Aug. 1	York	Prof. E. Ray Lankester, LL.D., F.R.S.	322	10
1907, July 31	Leicester	Sir David Gill, K.C.B., F.R.S.	276	19
1908, Sept. 2	Dublin	Dr. Francis Darwin, F.R.S.	294	24
1909, Aug. 25	Winnipeg	Prof. Sir J. J. Thomson, F.R.S.	117	13
1910, Aug. 31	Sheffield	Rev. Prof. T. G. Bonney, F.R.S.	293	26
1911, Aug. 30	Portsmouth	Prof. Sir W. Ramsay, K.C.B., F.R.S.	284	21
1912, Sept. 4	Dundee	Prof. E. A. Schäfer, F.R.S.	288	14
1913, Sept. 10	Birmingham	Sir Oliver J. Lodge, F.R.S.	376	40
1914 July-Sept.	Australia	Prof. W. Bateson, F.R.S.	172	13
1915, Sept. 7	Manchester	Prof. A. Schuster, F.R.S.	242	19
1916, Sept. 5	Newcastle-on-Tyne	Sir Arthur Evans, F.R.S.	164	12
1917	(No Meeting)		—	—
1918	(No Meeting)		—	—
1919, Sept. 9	Bournemouth	Hon. Sir C. Parsons, K.C.B., F.R.S.	235	47
1920, Aug. 24	Cardiff	Prof. W. A. Herdman, C.B.E., F.R.S.	288	11
1921, Sept. 7	Edinburgh	Sir T. E. Thorpe, C.B., F.R.S.	336	9
1922, Sept. 6	Hull	Sir C. S. Sherrington, G.B.E., Pres. R.S.	228	13
1923, Sept. 12	Liverpool	Sir Ernest Rutherford, F.R.S.	326	12
1924, Aug. 6	Toronto	Sir David Bruce, K.C.B., F.R.S.	119	7
1925, Aug. 26	Southampton	Prof. Horace Lamb, F.R.S.	280	8
1926, Aug. 4	Oxford	H.R.H. The Prince of Wales, K.G., F.R.S.	358	9

[1] Including 848 Members of the South African Association.
[2] Including 137 Members of the American Association.
[3] Special arrangements were made for Members and Associates joining locally in Australia, see Report, 1914, p. 686. The numbers include 80 Members who joined in order to attend the Meeting of L'Association Française at Le Havre.
[4] Including Students' Tickets, 10*s*.
[5] Including Exhibitioners granted tickets without charge.

Annual Meetings—(continued).

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received for Tickets	Sums paid on account of Grants for Scientific Purposes	Year
297	45	801	482	9	1915	£1801 0	£1072 10 0	1900
374	131	794	246	20	1912	2046 0	920 9 11	1901
314	86	647	305	6	1620	1644 0	947 0 0	1902
319	90	688	365	21	1754	1762 0	845 13 2	1903
449	113	1338	317	121	2789	2650 0	887 18 11	1904
937[1]	411	430	181	16	2130	2422 0	928 2 2	1905
356	93	817	352	22	1972	1811 0	882 0 9	1906
339	61	659	251	42	1647	1561 0	757 12 10	1907
465	112	1166	222	14	2297	2317 0	1157 18 8	1908
290[2]	162	789	90	7	1468	1623 0	1014 9 9	1909
379	57	563	123	8	1449	1439 0	963 17 0	1910
349	61	414	81	31	1241	1176 0	922 0 0	1911
368	95	1292	359	88	2504	2349 0	845 7 6	1912
480	149	1287	291	20	2643	2756 0	978 17 1	1913
139	4160[3]	539[3]	—	21	5044[3]	4873 0	1861 16 4[6]	1914
287	116	628[4]	141	8	1441	1406 0	1569 2 8	1915
250	76	251[4]	73	—	826	821 0	985 18 10	1916
—	—	—	—	—	—	—	677 17 2	1917
—	—	—	—	—	—	—	326 13 3	1918
254	102	688[4]	153	3	1482	1736 0	410 0 0	1919

Old Annual Regular Members	Annual Members: Meeting and Report	Annual Members: Meeting only	Transferable Tickets	Students Tickets	Foreigners	Total	Amount received for Tickets	Sums paid on account of Grants for Scientific Purposes	Year
136	192	571	42	120	20	1380	1272 10	1251 13 0[8]	1920
133	410	1394	121	343	22	2768	2599 15	518 1 10	1921
90	294	757	89	235[5]	24	1730	1699 5	772 0 7	1922
					Complimentary.				
123	380	1434	163	550	308[7]	3296	2735 15	777 18 6[9]	1923
37	520	1866	41	89	139	2818	3165 19[10]	1197 5 9	1924
97	264	878	62	119	74	1782	1630 5	1231 0 0	1925
101	453	2338	169	225	69	3722	3542 0	917 1 6	1926

[6] Including grants from the Caird Fund in this and subsequent years.
[7] Including Foreign Guests, Exhibitioners, and others.
[8] The Bournemouth Fund for Research, initiated by Sir C. Parsons, enabled grants on account of scientific purposes to be maintained.
[9] Including grants from the Caird Gift for research in radioactivity in this and subsequent years to 1926.
[10] Subscriptions paid in Canada were $5 for Meeting only and others pro rata; there was some gain on exchange.

REPORT OF THE COUNCIL, 1925—26.

I. The Council presented an address of condolence to The King on the death of Queen Alexandra, and received His Majesty's gracious acknowledgment.

II. The Council presented a resolution of welcome and congratulation to H.R.H. The Prince of Wales, President-elect, on his return from South Africa and South America, and received The Prince's gracious acknowledgment.

III. The Council has had to deplore the loss by death of Sir Francis Darwin (President, 1908); of Mr. W. Bateson (President, 1914), who was to have presided over Section K (Botany) at the Oxford Meeting; of Dr. W. Evans Hoyle, local secretary for the Cardiff Meeting in 1920 and a recent member of the Council; and, among other supporters and former office-bearers, Prof. A. R. Cushny, Prof. F. Y. Edgeworth, Mr. J. S. Gamble, Prof. A. Gray, Mr. W. P. Hiern, Prof. J. W. Langley, and the Rev. T. R. R. Stebbing.

IV. Prof. Sir Arthur Keith, F.R.S., has been unanimously nominated by the Council to fill the office of President of the Association for the year 1927-28 (Leeds Meeting).

V. Representatives of the Association have been appointed as follows:—

Carnegie U. K. Trustees' Conference on Museums as a factor in Education	Dr. H. Bolton.
American Association for the Advancement of Science, Kansas City Meeting	Prof. J. C. Fields and Prof. W. A. Parks.
French Society of Chemical Industry, Paris, Oct. 1925	Sir W. Pope.
Sheffield University, Coming-of-Age, June 30, 1926	Mr. F. E. Smith.
Congress of Chemical Industry, Brussels, September, 1926	Sir W. Pope.

VI. Resolutions referred by the General Committee at the Southampton Meeting to the Council for consideration, and, if desirable, for action, were dealt with as follows:—

(*a*) The Council adopted by a majority a resolution that invitations to attend the Oxford Meeting should be issued to eminent scientists irrespective of nationality.

The temporary suspension of honorary corresponding membership, applied in 1919 in the case of certain foreign scientific men, has been removed.

(*b*) The Council regrets that the railway authorities do not see their way to including scientific parties specifically in the regulations governing the issue of return period tickets. (Resolutions of Sections C, D, E.)

(*c*) The Council referred to the Board of Education a resolution inviting consideration of an amendment of a clause in Circular 826 (1913), permitting in certain events the curtailment or discontinuance of instruction in geography. (Resolution of Section E.)

(*d*) The Council recommended Miss W. S. Blackman to the Egyptian and other authorities for assistance in her investigation of the culture of the peasant population of modern Egypt. The Council regrets that its preliminary endeavours have been without result. (Resolution of Section H.)

(*e*) In regard to resolutions of Sections E, H, and M relating to the Report of the East African Commission (upon which the General Committee itself took action), the Council learned with satisfaction from H.M. Secretary of State for the Colonies that scientific research is receiving attention and financial support in the territories of East Africa, and that the Amani Institute is being revived.

(*f*) The Council referred to the Ministry of Agriculture and the Board of Education a resolution dealing with the facilities offered by local scientific societies for supplementing the curriculum of schools in matters bearing upon local geography, natural history, and antiquities, and communicated their replies to the Corresponding Societies, recommending individual consultation with local education authorities by any societies which might find this desirable. (Resolution of the Conference of Delegates.)

(*g*) The Council has been in correspondence with interested parties in relation to the spoliation of ancient monuments on Dartmoor for road-metal. (Resolution of the Conference of Delegates.)

(*h*) The Council has received and approved a report on regional survey from the Corresponding Societies Committee, which has been communicated to the Societies. (Resolution of the Conference of Delegates.)

(*i*) The Council referred to the British Correlating Committee for the Protection of Nature a resolution asking for inquiry into the threatened extermination of many rarer British plants and animals. The Committee asked that any information should be passed to it, and Corresponding Societies have been notified accordingly. (Resolution of the Conference of Delegates.)

VII. The Council resolved that the list of papers bearing on zoology, botany, and prehistoric archæology published in connection with the Report of the Corresponding Societies Committee should be discontinued after the present year, as it was not found to be of sufficiently wide use to justify the expenditure upon it. Mr. T. Sheppard received the thanks of the Council for his unsparing work in the preparation of the list.

The Council proposes to omit from Rule XI., 3, reference to the preparation of a list of papers published by the Corresponding Societies.

VIII. The Council reported last year upon the discussion, for which the Toronto Meeting afforded occasion, upon an international abstracting service for biological sciences. Having learned from the Royal Society during the present year that the American authorities had decided not to propose any formal co-operation with the Society, the Council conveyed to them its thanks for the opportunity which they had given the Association of discussing the matter.

IX. In regard to the question of the distribution of Government scientific publications for review and of reprints to authors, which also

had been previously before the Council, careful inquiry failed to reveal the necessity for formally bringing the matter to the notice of H.M. Treasury; it appeared that any individual cases of difficulty would receive sympathetic consideration from the authorities concerned.

X. In co-operation with the British Science Guild, the Council summoned a conference of representatives of leading scientific Societies to consider the desirability and possibility of establishing a science news service, and a committee was appointed to deal further with this matter.

XI. The Council has received reports from the General Treasurer throughout the year. His accounts have been audited and are presented to the General Committee. The Council made the following grants to research committees from the Caird Fund:—

	£		£
Naples Table	100	Marine Laboratory, Plymouth	20
Seismology	100	Zoological Record	35
Tables of Constants ...	5	Bronze Implements	80
Upper Atmosphere ...	38	Index Kewensis	70
Colloid Chemistry ...	5	Kent's Cavern	10
Quaternary Peats ...	38	Corresponding Societies Committee	40

and a donation of £10 10s. to the Optical Convention, 1926.

Having regard to the exceptional circumstances of the Oxford Meeting (namely the possibility of an unusually large attendance at a meeting in a non-industrial area, involving unusual expenditure upon entertainment, etc., in a locality where financial resources might be found to be restricted), the Council agreed with the Local Executive Committee that from any receipts for membership tickets in excess of £2,500 (exclusive of life compositions and payments for the Report) the sum of 5s. in the pound should be earmarked as a guarantee fund to supplement the local fund if necessary. Further, the Local Executive Committee having decided that each subscriber of £5 and upwards to the local fund should be given a membership ticket, it was agreed that the sum of 15s. instead of one pound should be payable to the Association as the price of each such ticket.

The General Treasurer, with the authority of the Council and the assistance of a Committee, has had under consideration the possibility of increasing the capital funds of the Association by means of an appeal.

The remaining balance of accrued interest upon the Caird Gift for research in radio-activity has been granted, for the year 1926-27, as to £50 each to Mr. P. Blackett, Dr. J. Chadwick, and Dr. A. S. Russell, any balance remaining from the income of the gift being brought into general funds and earmarked as available for a grant to any Committee of the Association appointed in the future to undertake research in radio-activity. The trust fund is thus finally disposed of.

XII. At the instance of certain of the Corresponding Societies, upon which demands for the payment of income tax, previously remitted, have recently been made, a full inquiry was undertaken, and after consultation with the Society of Antiquaries and societies in union therewith, and with other leading societies, a joint deputation discussed

the question with the Financial Secretary to the Treasury, and a committee subsequently met representatives of the Board of Inland Revenue. It was proposed by the Board that a test case should be brought against two selected societies during the year 1926-27, H.M. Treasury bearing costs according to an agreed scale irrespective of the decision, and to this course the Council, on the part of the Association, agreed. Discussion and arrangements are proceeding.

XIII. The Corresponding Societies Committee has been nominated as follows: the President of the Association (*Chairman ex-officio*), Mr. T. Sheppard (*Vice-Chairman*), the General Treasurer, the General Secretaries, Dr. F. A. Bather, Sir R. A. Gregory, Sir D. Prain, Sir J. Russell, Mr. Mark Sykes, Dr. C. Tierney.

XIV. The retiring Ordinary Members of the Council are: Dr. F. W. Aston, Mr. E. Barker, Sir Daniel Hall, Dr. P. Chalmers Mitchell, and Mr. A. G. Tansley.

The Council nominates the following new members:—Professor J. P. Hill, Sir John Russell, Professor A. C. Seward; leaving two vacancies to be filled by the General Committee without nomination by the Council.

The full list of nominations of Ordinary Members is as follows:—

Professor J. H. Ashworth.
Sir W. H. Beveridge.
Rt. Hon. Lord Bledisloe.
Professor A. L. Bowley.
Professor E. G. Coker.
Professor W. Dalby.
Dr. H. H. Dale.
Professor C. H. Desch.
Mr. E. N. Fallaize.
Sir J. S. Flett.
Professor H. J. Fleure.
Sir R. A. Gregory.
Mr. C. T. Heycock.
Professor J. P. Hill.
Sir T. H. Holland.
Dr. C. S. Myers.
Professor T. P. Nunn.
Professor A. W. Porter.
Professor A. O. Rankine.
Sir J. Russell.
Professor A. C. Seward.
Dr. F. C. Shrubsall.
Professor A. Smithells.

XV. The General Officers have been nominated by the Council as follows:—

General Treasurer, Dr. E. H. Griffiths.

General Secretaries, Prof. J. L. Myres, Mr. F. E. Smith.

XVI. The following have been admitted as members of the General Committee:—

Mrs. N. L. Alcock.
Mr. A. Leslie Armstrong.
Dr. A. Bramley.
Dr. Winifred E. Brenchley.
Dr. W. T. Calman.
Miss C. Coignou.
Dr. E. P. Farrow.
Mr. G. A. Garfitt.
Mr. W. Godden.
Sir J. B. Henderson.
Dr. H. Henstock.
Prof. G. Hickling.
Mr. R. H. Kinvig.
Mr. H. Knox-Shaw.
Miss M. A. Murray.
Mr. G. Leslie Purser.
Mr. W. P. Pycraft.
Dr. J. H. Shaxby.
Dr. T. A. Stephenson.
Dr. H. Hamshaw Thomas.

XVII. Inquiry has been received as to the possibility of the Association favourably considering an invitation to meet in South Africa in or about 1929. The Council had the advantage of discussing the matter with Prof. H. B. Fantham (Johannesburg), and promised to refer any such proposal to the General Committee for its sympathetic consideration.

BRITISH ASSOCIATION EXHIBITIONS.

For the Oxford Meeting, British Association Exhibitions (referred to in § IX. of the Report of the Council, 1922-23) were awarded to nineteen students nominated by the same number of universities and colleges. Their travelling expenses (railway fares) were met by the Association, which also issued complimentary students' tickets of membership to them; they were entertained in Oxford by various colleges, &c., arrangements being made by the Local Executive Committee. Eight of the universities or colleges allowed expenses for twenty-six additional exhibitioners, while five selected students from Liverpool received grants for the same purpose out of a fund formed from the surplus of the moneys collected for the local fund in connection with the Liverpool Meeting, 1923. The exhibitioners were presented to the President, H.R.H. The Prince of Wales, in Magdalen College on August 5. Two of their number (Mr. H. G. Littler, Liverpool, and Mr. L. L. Barnes, King's College, London) were elected respectively president and secretary of the exhibitioners for the purpose of communication by them as a body with the general officers.

GENERAL MEETINGS, ETC., IN OXFORD.

The Inaugural General Meeting was held on Wednesday, August 4, 1926, at 8.30 p.m. The proceedings took place in the Sheldonian Theatre, and were relayed to the Town Hall and to the hall of the Union Society. After the Vice-Chancellor of the University and the Rt. Worshipful the Mayor of Oxford had welcomed the Association, Prof. Horace Lamb, F.R.S., resigned the office of President of the Association to H.R.H. The Prince of Wales, K.G., F.R.S. The new President, after communicating to the meeting a gracious Message from his Majesty the King, and the terms of his reply, delivered an Address (for which see p. 1). The Rt. Hon. the Earl of Balfour, K.G., O.M., F.R.S., ex-President, proposed a vote of thanks to the President, which was carried by acclamation.

On the conclusion of the proceedings in the Sheldonian Theatre the President was escorted by the Mayor to the Town Hall. He was received there by Prof. H. H. Turner, F.R.S., ex-general secretary of the Association, who had occupied the chair, and by principal representatives of the city, and briefly addressed the audience which had heard the relayed proceedings. The chair at the meeting in the Union Society's hall was taken by Prof. E. B. Poulton, F.R.S.

On Thursday evening, August 5, receptions were given by the Vice-Chancellor in the Examination Schools, by the Rt. Worshipful the Mayor in the Town Hall, and by the Dean, Canons and Students of Christ Church in Christ Church, all of which were honoured by the presence of the President.

Evening Discourses.

Prof. A. S. Eddington, F.R.S.: 'Stars and Atoms.' 8 p.m., August 6, Union Society's Hall.

Prof. H. Fairfield Osborn, For. Mem. R.S.: 'Discoveries in the Gobi Desert by the American Museum Expeditions.' 8 p.m., August 9, Town Hall.

Citizens' Lectures.

Prof. P. F. Kendall, F.R.S.: 'Coal.' 8.30 p.m., August 5, Union Society's Hall.

Capt. P. P. Eckersley: 'Wireless.' 8.30 p.m., August 6, Town Hall.

Sir Dugald Clerk, K.B.E., F.R.S.: 'The Rise of the Internal Combustion Engine.' 5.30 p.m., August 7, Union Society's Hall.

Sir William Bragg, K.B.E., F.R.S.: 'Necessity is the Mother of Invention.' 8.30 p.m., August 9, Union Society's Hall.

Prof. Julian Huxley: 'Animal Courtship.' 8.30 p.m., August 10, Union Society's Hall.

Lectures to Young People.

Prof. W. Garstang: 'The Songs of Birds.' 10.30 a.m., August 6, Electra Palace Cinema.

Mr. O. G. S. Crawford: 'A Day in the Life of a Cave Man.' 10.30 a.m., August 10, Oxford Super-Cinema.

Concluding General Meeting.

The concluding General Meeting was held in the Examination Schools on Wednesday, August 11, at 12 noon, Sir Oliver Lodge, F.R.S., ex-President, in the chair. The following letter from the President was read to the meeting:—

St. James's Palace, London, S.W.1.

As it has unfortunately not been possible for me to return to Oxford for the conclusion of our Meeting, I must ask the General Secretaries to convey to the Council my warmest congratulations on the success of what I hope will prove to have been one of the most successful of the British Association's annual gatherings.

To that result, many people, both within and without the Association, have contributed. In the first class are our General Officers, whose admirable preliminary arrangements ensured the smooth working of the Meeting as a whole and of its many separate units; our Sectional Officers, on whom rested the responsibility of organising those units; and, not least, the rank and file of our members, whose enthusiasm and devotion to the cause of Science has been a great inspiring force.

Secondly, there are our hosts in the University and City of Oxford, who have thrown open their wonderful heritage to all of us, and shown us unwearying kindness; and our guests, who, by their very presence and by the added weight of learning which they have given to our proceedings, have emphasised the all-important fact that Science works not for one nation, or even one race, but for the common good of all living things.

All of these deserve our heartfelt thanks, and I consider it a high honour to be able, as President of the Association, to express them.

Lord Balfour, at our inaugural session, suggested that the future harvest, of which this Meeting is the seed-time, might be a notable one. I do not know how far this prophecy is likely to be justified in the immediate future. But, from what I saw during my stay in Oxford, I do feel confident that there is alive in the army of scientific workers to-day a spirit of enthusiasm and energy which cannot fail to achieve great things. I strongly hope that at any rate the coming shadow of such achievement, if not the achievement itself, may be visible before the close of my Presidency a year hence.

(Signed) EDWARD P.,
President.

August 10, 1926.

The following reply was adopted and ordered to be forwarded to the President:

Oxford,
August 11, 1926.

To His Royal Highness
The Prince of Wales, our President.

SIR,

At the Concluding General Meeting of the British Association, held in Oxford to-day, Your Royal Highness' gracious message as President has been read and received with acclamation. We desire most gratefully to express our deep sense of the personal sympathy with our aims and endeavours, and the keen interest in our proceedings, which made your presence among us memorable. Especially do we appreciate the significance of the Address with which you inaugurated the meeting, and the high ideal of co-operation between research and administration which you have set before us all and before the wider public by whom your words were heard.

We return to our work in the confidence that your year of office as President, so auspiciously begun, will be fruitful of benefit to the Association and to the advancement of science.

I am, Sir,

Your Royal Highness' obedient servant,

(Signed) OLIVER LODGE,
Ex-President, Chairman.

The following Resolution was then adopted with acclamation:

At the conclusion of a memorable meeting, the British Association for the Advancement of Science thanks the University and City of Oxford for the unbounded hospitality with which the Association has been received, and for the generous opportunities afforded its members to prosecute their labours and enjoy their recreations in an environment previously endeared to many of them, and unsurpassed in its manifold interests for them all.

EXTERNAL LECTURES.

Public lectures were given, in connection with the Oxford Meeting:—At Banbury, by Mr. H. J. E. Peake, on 'The Beginnings of Civilisation'; at Swindon, by Prof. H. E. Roaf, on 'The Effect of Sun-light on Health'; at Abingdon, by Mr. C. P. Chatwin, on 'The Geology of the Neighbourhood of Abingdon'; at Wantage, by Dr. T. F. Chipp, on 'The Work of Botanic Gardens'; and at Newbury, by Mr. C. J. P. Cave, on 'Climatic Conditions.'

GENERAL TREASURER'S ACCOUNT

JULY 1, 1925, TO JUNE 30, 1926.

NOTE.

Special arrangements in connection with the Oxford Meeting led to the payment of an unusually large number of membership subscriptions in advance. The total of the sums on account of these items amounts to £1,666 10*s.*; last year under normal working the corresponding sum was £339 10*s.* This difference of £1,327 accounts for the £1,327 2*s.* 8*d.* stated as 'excess of income over expenditure.'

Again, in order to meet, however inadequately, the applications for grants to Research Committees received at Southampton, the Council had to utilise the accumulations of income in the Caird Fund, and draw on that fund to the extent of £185 above the year's income.

Thus, apart from the excess pre-payments above referred to and the utilisation of the Caird accumulation, the year's working shows a deficiency of £185.

E. H. GRIFFITHS.

Balance Shee

Corresponding Figures 1925. £ s. d.	LIABILITIES.	£ s. d.	£ s.
10,575 15 2	To Capital Accounts— General Fund, as per contra . . . (Subject to Depreciation in Value of Investments)		10,575 15
9,582 16 3	,, Caird Fund— As per contra . . . . . . (Subject to Depreciation in Value of Investments)		9,582 16
	,, Caird Fund— Revenue Account, Balance as at July 1, 1925	655 14 2	
655 14 2	*Less* Excess of Expenditure over Income for the year	185 9 4	470 4 1
	,, Caird Gift, Radio-Activity Investigations— Balance as at July 1, 1925	249 18 11	
	Add Income Tax recovered . . .	2 5 0	
		252 3 11	
249 18 11	*Less* Grants paid	200 0 0	52 3 1
62 11 8	,, Sir F. Bramwell's Gift for Enquiry into Prime Movers, 1931— £50 Consols now accumulated to £132 12*s.* 9*d.*, as per contra		65 16
10,000 0 0	,, Sir Charles Parsons' Gift		10,000 0
75 0 0	,, John Perry Guest Fund— For cases of emergency connected with Guests of the Association		75 0
	,, Life Compositions— As at July 1, 1925	708 12 2	
708 12 2	*Add* Received during year . . .	225 0 0	933 12
450 0 0	,, Legacy—T. W. Backhouse		450 0
	,, Toronto University Presentation Fund . .	178 11 4	
	Add Dividends	4 7 6	182 18 1
	,, Income and Expenditure Account— Balance as at July 1, 1925	3,217 15 10	
3,505 6 8	*Add* Balance being Excess of Income over Expenditure for the year . . .	1,327 2 8	4,544 18
35,865 15 0			£36,933 5

I have examined the foregoing Account with the Books and Vouchers and certify the sam
Approved,

ARTHUR L. BOWLEY, } *Auditors.*
A. W. KIRKALDY,

July 9, 1926.

June 30, 1926.

ASSETS.

Corresponding Figures 1925. £ s. d.		£ s. d.	£ s. d.
	By Investments on Capital Accounts—General Fund—		
	£4,651 10*s.* 5*d.* Consolidated 2½ per cent. at cost	3,942 3 3	
	£3,600 India 3 per cent. Stock at cost. .	3,522 2 6	
	£879 14*s.* 9*d.* £43 Great Indian Peninsula Railway 'B' Annuity at cost . . .	827 15 0	
	£52 12*s.* 7*d.* War Stock (Post Office Issue) at cost	54 5 2	
	£834 16*s.* 6*d.* 4½ per cent. Conversion Loan at cost	835 12 4	
10,575 15 2	£1,400 War Stock 5 per cent. 1929/47 at cost	1,393 16 11	10,575 15 2
	£7,605 2s. 11d. Value at date, £7,880 18*s.* 8*d.*		
	,, Caird Fund—		
	£2,627 0*s.* 10*d.* India 3½ per cent. Stock at cost	2,400 13 3	
	£2,100 London Midland and Scottish Railway Consolidated 4 per cent. Preference Stock at cost	2,190 4 3	
	£2,500 Canada 3½ per cent. 1930/50 Registered Stock at cost	2,397 1 6	
9,582 16 3	£2,000 Southern Railway Consolidated 5 per cent. Preference Stock at cost . . .	2,594 17 3	9,582 16 3
	£7,045 16s. 1d. Value at date, £7,343 18*s.* 7*d.*		
655 14 2	,, Caird Fund Revenue Account— Cash at Bank		470 4 10
249 18 11	,, Caird Gift— Cash at Bank		52 3 11
	,, Sir F. Bramwell's Gift— £126 17 6 Self-Accumulating Consolidated Stock as per last Balance Sheet	62 11 8	
62 11 8	5 15 3 *Add* Accumulations to June 30, 1926 . . .	3 4 4	65 16 0
	£132 12 9		
10,000 0 0	,, Sir Charles Parsons' Gift— £10,300 4½ per cent. Conversion Loan . *£9,682* Value at date, £9,888		10,000 0 0
	,, John Perry Guest Fund— £96 National Savings Certificates at cost .	74 8 0	
75 0 0	Cash at Bank	0 12 0	75 0 0
	,, Life Compositions— £1,403 6*s.* 7*d.* Local Loans at cost . .	915 0 0	
708 12 2	Cash at Bank	18 12 2	933 12 2
450 0 0	,, Legacy—T. W. Backhouse— Cash at Bank		450 0 0
	,, Toronto University Presentation Fund— £175 5 per cent. War Stock at cost . .	178 11 4	
	Cash at Bank	4 7 6	182 18 10
	,, Revenue Account— £2,098 1*s.* 9*d.* Consolidated 2½ per cent. Stock at cost	1,200 0 0	
	£1,949 8*s.* 9*d.* Conversion 3½ per cent. Stock at cost	1,500 0 0	
	Sundry Debtors and payments in advance .	153 3 6	
	Cash at Bank	1,679 11 4	
3,505 6 8	Cash in Hand	12 3 8	4,544 18 6
35,865 15 0			£36,933 5 8

to be correct. I have also verified the Balances at the Bankers and the Investments.

W. B. KEEN,
Chartered Accountant.

Income and

FOR THE YEAR ENDED

EXPENDITURE.

Corresponding Period 1925. £ s. d.		£ s. d.	£ s. d.
20 3 1	To Heat, Lighting and Power	25 13 2	
45 7 9	,, Stationery	71 5 7	
1 0 0	,, Rent	1 0 0	
176 1 8	,, Postages	140 12 7	
78 11 2	,, Travelling Expenses	121 15 5	
60 0 0	,, Exhibitioners	36 12 9	
245 10 4	,, General Expenses	187 3 4	
914 16 3	,, *Lift and Preparing Well, etc.*		
261 8 0	,, *Decorations and Improvements*		
1,802 18 3		584 2 10	
1,202 10 0	,, Salaries, Wages, etc.	1,184 19 2	
75 0 0	,, Pension Contribution	75 0 0	
1,675 12 5	,, Printing, Binding, etc.	1,466 17 5	
4,756 0 8			3,310 19 5
	,, *Sir Robert Hadfield's Gift—*		
50 0 0	*Grants to Universities*		
8,421 13 4	,, *Grants made in aid of Expenses, etc.,* re *Toronto Meeting out of moneys received from Dominion Government of Canada, as per contra*		
	,, Grants to Research Committees—		
	Growth in Children Committee	20 0 0	
	Old Red Sandstone of Bristol Committee	6 0 0	
	Sumerian Copper Committee	9 15 0	
	Overseas Training Committee	7 0 0	
	Triplets Committee	20 0 0	
	Palaeozoic Rocks Committee	15 0 0	
	Medullary Centres Committee	18 0 0	
	Palaeolithic Implements Committee	20 0 0	
	London Tertiary Rocks Committee	10 0 0	
	Geography Teaching Committee	2 16 6	
	Oxfordshire Anthropological Investigations Committee	10 0 0	
	Vocational Tests Committee	14 0 0	
	Old Red Sandstone of Kiltorcan, Ireland, Committee	8 0 0	
451 0 0	Cost of Cycling Committee	10 0 0	
			170 11 6
	,, Balance being Excess of Income over Expenditure for the year		1,327 2 8
13,678 14 0			£4,808 13 7

Caird

EXPENDITURE.

£ s. d.		£ s. d.	£ s. d.
	To Grants Paid—		
	Index Kewensis Committee	70 0 0	
	Quaternary Peats Committee	38 0 0	
	Corresponding Societies Committee	40 0 0	
	Zoological Record Committee	35 0 0	
	Marine Laboratory, Plymouth, Committee	20 0 0	
	Optical Convention	10 10 0	
	Seismology Committee	100 0 0	
	Kent's Cavern Committee	10 0 0	
	Bronze Implements Committee	80 0 0	
	Colloid Chemistry Committee	5 0 0	
	Naples Tables Committee	100 0 0	
430 0 0	Upper Atmosphere Investigations Committee	38 0 0	
			546 10 0
430 0 0			£546 10 0

Expenditure Account

JUNE 30, 1926.

Corresponding Period 1925. £	s.	d.	INCOME.	£	s.	d.	£	s.	d.
207	*4*	*6*	By Annual Members (Including £95, 1926/27, and £1, 1927/28)				249	0	0
1,956	*19*	*8*	„ Annual Temporary Members (Including £1,031, 1926/27)				1,806	0	0
870	*3*	*11*	„ Annual with Report (Including £430, 1926/27)				732	0	0
56	*0*	*4*	„ Transferable Tickets (Including £67 10*s*., 1926/27)				148	15	0
50	*18*	*8*	„ Students' Tickets (Including £38 10*s*., 1926/27)				92	10	0
50	*3*	*0*	„ Donations				5	0	0
51	*7*	*11*	„ Interest on Deposit				52	12	4
613	*15*	*7*	„ Sale of Publications				581	13	11
			„ Advertisement Revenue				167	0	3
40	*6*	*3*	„ Income Tax recovered				157	13	10
90	*12*	*6*	„ Unexpended Balance of Grants returned. .				24	2	10
50	*0*	*0*	„ *Sir Robert Hadfield's Gift*						
8,421	*13*	*4*	„ *Dominion Government of Canada for expenses re Toronto Meeting, as per contra* . . .						
			„ Dividends—						
			£140 5 5 — Consols	£135	0	0			
			95 17 0 — India 3 per cent.	86	8	0			
			25 15 11 — Great Indian Peninsula 'B' Annuity.	26	9	0			
			16 19 8 — 4½ per cent. Conversion Loan . .	30	1	2			
			209 10 11 — Ditto Sir Charles Parsons' Gift . .	370	16	0			
			3½ per cent. Conversion Loan . .	54	11	8			
			60 1 3 — *Treasury Bonds*						
			16 7 10 — Local Loans	30	7	1			
			57 15 0 — War Stock	58	12	6			
622	*13*	*0*					792	5	5
596	*15*	*4*	*By Balance being Excess of Expenditure over Income for the year*						
13,678	*14*	*0*					£4,808	13	7

Fund.

£	s.	d.	INCOME.	£	s.	d.	£	s.	d.
			By dividends—						
			India 3½ per cent.	73	11	0			
			Canada 3½ per cent.	70	0	0			
			London Midland and Scottish Railway Consolidated 4 per cent. Preference Stock .	66	13	6			
			Southern Railway Consolidated 5 per cent. Preference Stock	79	7	6			
292	*0*	*0*					289	12	0
62	*4*	*10*	„ Income Tax recovered				71	8	8
75	*15*	*2*	„ Balance being Excess of Expenditure over Income for year.				185	9	4
430	*0*	*0*					£546	10	0

RESEARCH COMMITTEES, Etc.

APPOINTED BY THE GENERAL COMMITTEE, MEETING IN OXFORD, 1926.

Grants of money, if any, from the Association for expenses connected with researches are indicated in heavy type.

Seismological Investigations.—Prof. H. H. Turner (*Chairman*), Mr. J. J. Shaw (*Secretary*), Mr. C. Vernon Boys, Dr. J. E. Crombie, Dr. C. Davison, Sir F. W. Dyson, Sir R. T. Glazebrook, Dr. H. Jeffreys, Prof. H. Lamb, Sir J. Larmor, Prof. A. E. H. Love, Prof. H. M. Macdonald, Dr. A. Crichton Mitchell, Mr. R. D. Oldham, Prof. H. C. Plummer, Mr. W. E. Plummer, Rev. J. P. Rowland, S.J., Prof. R. A. Sampson, Sir A. Schuster, Sir Napier Shaw, Sir G. T. Walker, Mr. F. J. W. Whipple. **£100** (Caird Fund grant).

Tides.—Prof. H. Lamb (*Chairman*), Dr. A. T. Doodson (*Secretary*), Dr. G. R. Goldsbrough, Dr. H. Jeffreys, Prof. J. Proudman, Prof. G. I. Taylor, Prof. D'Arcy W. Thompson, Commander H. D. Warburg.

Annual Tables of Constants and Numerical Data, chemical, physical, and technological. —Sir E. Rutherford (*Chairman*), Prof. A. W. Porter (*Secretary*), Mr. Alfred Egerton. **£5.**

Calculation of Mathematical Tables.—Prof. J. W. Nicholson (*Chairman*), Dr. J. R. Airey (*Secretary*), Mr. T. W. Chaundy, Dr. A. T. Doodson, Prof. L. N. G. Filon, Mr. R. A. Fisher, Prof. E. W. Hobson, and Profs. Alfred Lodge, A. E. H. Love, and H. M. Macdonald.

Investigation of the Upper Atmosphere.—Sir Napier Shaw (*Chairman*), Mr. C. J. P. Cave (*Secretary*), Prof. S. Chapman, Mr. J. S. Dines, Mr. L. H. G. Dines, Mr. W. H. Dines, Dr. G. M. Dobson, Commr. L. G. Garbett, Sir R. T. Glazebrook, Col. E. Gold, Dr. H. Jeffreys, Dr. H. Knox-Shaw, Sir J. Larmor, Mr. R. G. K. Lempfert, Prof. F. A. Lindemann, Dr. W. Makower, Mr. J. Patterson, Sir J. E. Petavel, Sir A. Schuster, Dr. G. C. Simpson, Sir G. T. Walker, Mr. F. J. W. Whipple, Prof. H. H. Turner. **£70.**

To investigate local variations of the Earth's Gravitational Field.—Col. Sir H. G. Lyons (*Chairman*), Capt. H. Shaw (*Secretary*), Mr. C. Vernon Boys, Dr. C. Chree, Col. Sir G. P. Lenox-Conyngham, Dr. J. W. Evans, Mr. E. Lancaster-Jones; the Director-General, Ordnance Survey; the Director, Geological Survey of Great Britain.

SECTION B.—CHEMISTRY.

Colloid Chemistry and its Industrial Applications.—Prof. F. G. Donnan (*Chairman*), Dr. W. Clayton (*Secretary*), Mr. E. Hatschek, Prof. W. C. McC. Lewis, Prof. J. W. McBain. **£5.**

Absorption Spectra and Chemical Constitution of Organic Compounds.—Prof. I. M. Heilbron (*Chairman*), Prof. E. C. C. Baly (*Secretary*), Prof. A. W. Stewart. **£10.**

The Chemistry of Vitamins.—Sir F. G. Hopkins (*Chairman*), Prof. J. C. Drummond (*Secretary*), Prof. G. Barger, Prof. A. Harden, Sir J. C. Irvine, Prof. J. W. McBain, Prof. Lash Miller, Dr. S. Zilva. **£5.**

SECTION C.—GEOLOGY.

The Old Red Sandstone Rocks of Kiltorcan, Ireland.—Mr. W. B. Wright (*Chairman*), Prof. T. Johnson (*Secretary*), Dr. W. A. Bell, Dr. J. W. Evans, Prof. W. H. Lang, Sir A. Smith Woodward. **£10.**

To excavate Critical Sections in the Palæozoic Rocks of England and Wales.—Prof. W. W. Watts (*Chairman*), Prof. W. G. Fearnsides (*Secretary*), Mr. W. S. Bisat, Prof. W. S. Boulton, Mr. E. S. Cobbold, Mr. E. E. L. Dixon, Dr. Gertrude Elles, Prof. E. J. Garwood, Prof. H. L. Hawkins, Prof. V. C. Illing, Prof. O. T. Jones, Prof. J. E. Marr, Dr. T. F. Sibly, Dr. W. K. Spencer, Dr. A. E. Trueman. **£20**.

The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.—Prof. E. J. Garwood (*Chairman*), Prof. S. H. Reynolds (*Secretary*), Mr. G. Bingley, Mr. C. V. Crook, Mr. A. S. Reid, Prof. W. W. Watts, Mr. R. Welch.

To investigate the Quaternary Peats of the British Isles.—Prof. P. F. Kendall (*Chairman*), Mr. L. H. Tonks (*Secretary*), Prof. P. G. H. Boswell, Miss Chandler, Prof. H. J. Fleure, Dr. E. Greenly, Prof. J. W. Gregory, Prof. G. Hickling, Mr. J. de W. Hinch, Mr. R. Lloyd Praeger, Mrs. Reid, Dr. K. S. Sandford, Mr. T. Sheppard, Mr. J. W. Stather, Mr. A. W. Stelfox, Mr. C. B. Travis, Dr. A. E. Trueman, Mr. W. B. Wright. **£80**.

To investigate Critical Sections in the Tertiary Rocks of the London Area. To tabulate and preserve records of new excavations in that area.—Prof. W. T. Gordon (*Chairman*), Dr. S. W. Wooldridge (*Secretary*), Miss M. C. Crosfield, Prof. H. L. Hawkins, Prof. G. Hickling. **£10**.

To obtain Photographic Records of the Geological Effects of the 'débâcle' which resulted from the recent bursting of a dam at Dolgarrog, North Wales.—Dr. E. Greenly (*Chairman*), Mr. E. Montag (*Secretary*), Prof. P. G. H. Boswell, Prof. W. G. Fearnsides. **£5**.

SECTION D.—ZOOLOGY.

To aid competent Investigators selected by the Committee to carry on definite pieces of work at the Zoological Station at Naples.—Prof. E. S. Goodrich (*Chairman*), Prof. J. H. Ashworth (*Secretary*), Dr. G. P. Bidder, Prof. F. O. Bower, Sir W. B. Hardy, Sir S. F. Harmer, Prof. S. J. Hickson, Sir E. Ray Lankester, Prof. W. C. McIntosh. **£100** (Caird Fund grant).

Zoological Bibliography and Publication.—Prof. E. B. Poulton (*Chairman*), Dr. F. A. Bather (*Secretary*), Mr. E. Heron-Allen, Dr. W. T. Calman, Dr. P. Chalmers Mitchell, Mr. W. L. Sclater.

To nominate competent Naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.—Prof. J. H. Ashworth (*Chairman and Secretary*), Prof. W. J. Dakin, Prof. J. Stanley Gardiner, Prof. S. J. Hickson, Sir E. Ray Lankester. **£35**.

To co-operate with other Sections interested, and with the Zoological Society, for the purpose of obtaining support for the Zoological Record.—Sir S. Harmer (*Chairman*), Dr. W. T. Calman (*Secretary*), Prof. E. S. Goodrich, Prof. D. M. S. Watson. **£50**.

On the Influence of the Sex Physiology of the Parents on the Sex-Ratio of the Offspring. —Prof. W. J. Dakin (*Chairman*), Mrs. Bisbee (*Secretary*), Prof. Carr-Saunders, Miss E. C. Herdman. **£10**.

To report on the Pre-Linnean Zoological Collections and Specimens still extant in Great Britain, with a view to their safe custody.—Prof. E. S. Goodrich (*Chairman*), Dr. R. T. Gunther (*Secretary*).

To draw up recommendations for the taking and presentation of Biological Measurements, and to bring such before persons or bodies concerned.—Prof. J. S. Huxley (*Chairman*), Dr. R. A. Fisher (*Secretary*).

Investigations on Pigment in the Insecta.—Prof. W. Garstang (*Chairman*), Dr. J. W. Heslop Harrison (*Secretary*), Prof. E. B. Poulton, Prof. A. D. Peacock. **£15**.

Experimental investigation of the effects of Vasoligation, Cryptorchidism, Grafting, etc., on the Seminal Tubules and Interstitial Tissue of the Testes in Mammals. —Dr. F. A. E. Crew (*Chairman*), Mr. J. T. Cunningham (*Secretary*), Prof. J. S. Huxley. **£10**.

SECTION E.—GEOGRAPHY.

To consider the advisability of making a provisional Population Map of the British Isles, and to make recommendations as to the method of construction and reproduction.—Mr. H. O. Beckit (*Chairman*), Mr. F. Debenham (*Secretary*), Mr. J. Bartholomew, Dr. C. B. Fawcett, Prof. H. J. Fleure, Mr. R. H. Kinvig, Mr. A. G. Ogilvie, Mr. O. H. T. Rishbeth, Prof. P. M. Roxby, Lt.-Col. H. S. L. Winterbotham. **£25.**

To inquire into the present state of Geographical Knowledge of Tropical Africa, and to make recommendations for furtherance and development.—Sir Charles Lucas (*Chairman*), Mr. A. G. Ogilvie (*Secretary*), Mr. W. H. Barker, Mr. J. McFarlane, Prof. P. M. Roxby. **£5.**

SECTIONS E, L.—GEOGRAPHY, EDUCATION.

To formulate suggestions for a syllabus for the teaching of Geography both to Matriculation Standard and in Advanced Courses; to report upon the present position of the geographical training of teachers, and to make recommendations thereon; and to report, as occasion arises, to Council through the Organising Committee of Section E, upon the practical working of Regulations issued by the Board of Education (including Scotland) affecting the position of Geography in Training Colleges and Secondary Schools.—Prof. T. P. Nunn (*Chairman*), Mr. W. H. Barker (*Secretary*), Mr. L. Brooks, Prof. H. J. Fleure, Mr. O. J. R. Howarth, Sir H. J. Mackinder, Prof. J. L. Myres, Dr. Marion Newbigin, Mr. A. G. Ogilvie, Mr. A. Stevens, and Prof. J. F. Unstead (*from Section E*); Mr. D. Berridge, Mr. C. E. Browne, Sir R. Gregory, Mr. E. R. Thomas, Miss O. Wright (*from Section L*). **£5.**

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

To investigate certain aspects of Taxation in relation to the Distribution of Wealth.—Sir Josiah Stamp (*Chairman*), Mr. R. B. Forrester (*Secretary*), Prof. A. L. Bowley, Prof. E. Cannan, Prof. H. Clay, Mr. W. H. Coates, Miss L. Grier, Prof. H. M. Hallsworth, Prof. J. G. Smith.

Earth Pressures.—Mr. Wentworth Sheilds (*Chairman*), Dr. J. S. Owens (*Secretary*), Prof. G. Cook, Mr. P. M. Crosthwaite, Mr. T. E. N. Fargher, Prof. F. C. Lea, Mr. R. V. Southwell, Dr. R. E. Stradling, Dr. W. N. Thomas, Mr. E. G. Walker, Mr. J. S. Wilson. **£10.**

Electrical Terms and Definitions.—Sir John Snell (*Chairman*), Prof. Baily and Prof. G. W. O. Howe (*Secretaries*), Prof. W. Cramp, Prof. C. L. Fortescue, Prof. Sir James Henderson, Prof. E. W. Marchant, Dr. F. E. Smith.

SECTION H.—ANTHROPOLOGY.

To report on the Distribution of Bronze Age Implements.—Prof. J. L. Myres (*Chairman*), Mr. H. J. E. Peake (*Secretary*), Mr. Leslie Armstrong, Mr. H. Balfour, Prof. T. H. Bryce, Mr. L. H. Dudley Buxton, Mr. O. G. S. Crawford, Prof. H. J. Fleure, Dr. Cyril Fox, Mr. G. A. Garfitt. **£90.**

To conduct Archæological Investigations in Malta.—Prof. J. L. Myres (*Chairman*), Sir A. Keith (*Secretary*), Dr. T. Ashby, Mr. H. Balfour.

To conduct Explorations with the object of ascertaining the Age of Stone Circles.—Sir C. H. Read (*Chairman*), Mr. H. Balfour (*Secretary*), Dr. G. A. Auden, Dr. J. G. Garson, Sir Arthur Evans, Sir W. Boyd Dawkins, Prof. J. L. Myres, Mr. H. J. E. Peake.

To excavate Early Sites in Macedonia.—Prof. J. L. Myres (*Chairman*), Mr. S. Casson (*Secretary*), Dr. W. L. H. Duckworth, Mr. M. Thompson. **£40.**

To report on the Classification and Distribution of Rude Stone Monuments.—Mr. G. A. Garfitt (*Chairman*), Mr. E. N. Fallaize (*Secretary*), Mr. O. G. S. Crawford, Miss R. M. Fleming, Prof. H. J. Fleure, Dr. C. Fox, Mr. G. Marshall, Prof. J. L. Myres, Mr. H. J. E. Peake, Rev. Canon Quine.

The Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.—Mr. E. Torday (*Chairman*), Mr. E. N. Fallaize (*Secretary*), Dr. G. A. Auden, Dr. H. A. Auden, Mr. E. Heawood, Prof. J. L. Myres.

To report on the probable sources of the supply of Copper used by the Sumerians.—Mr. H. J. E. Peake (*Chairman*), Mr. G. A. Garfitt (*Secretary*), Mr. H. Balfour, Mr. L. H. Dudley Buxton, Prof. C. H. Desch, Mr. E. Mackay, Sir Flinders Petrie, Mr. C. Leonard Woolley.

To conduct Archæological and Ethnological Researches in Crete.—Dr. D. G. Hogarth (*Chairman*), Prof. J. L. Myres (*Secretary*), Dr. W. L. H. Duckworth, Sir A. Evans, Dr. F. C. Shrubsall.

To investigate the Culture of the Peasant Population of Modern Egypt.—Prof. J. L. Myres (*Chairman*), Mr. L. H. Dudley Buxton (*Secretary*), Mr. H. Balfour, Mr. E. N. Fallaize, Capt. Hilton Simpson, Prof. H. J. Rose. **£20**.

The Investigation of a hill fort site at Llanmelin, near Caerwent.—Mr. Willoughby Gardner (*Chairman*), Dr. Cyril Fox (*Secretary*), Dr. T. Ashby, Prof. H. J. Fleure, Mr. H. J. E. Peake, Prof. H. J. Rose, Dr. R. Mortimer Wheeler.

To co-operate with the Torquay Antiquarian Society in investigating Kent's Cavern.—Sir A. Keith (*Chairman*), Prof. J. L. Myres (*Secretary*), Dr. R. V. Favell, Mr. G. A. Garfitt, Prof. W. J. Sollas, Mr. Mark L. Sykes.

To conduct Anthropological investigations in some Oxfordshire villages.—Mr. H. J. E. Peake (*Chairman*), Mr. L. H. Dudley Buxton (*Secretary*), Dr. Vaughan Cornish, Miss R. M. Fleming, Prof. F. G. Parsons. **£10.**

To report on the present state of knowledge of the relation of early Palæolithic Implements to Glacial Deposits.—Mr. H. J. E. Peake (*Chairman*), Mr. E. N. Fallaize (*Secretary*), Mr. H. Balfour, Prof. P. G. H. Boswell, Mr. M. Burkitt, Prof. P. F. Kendall, Mr. G. Lamplugh, Prof. J. E. Marr. **£30.**

To co-operate with a Committee of the Royal Anthropological Institute in the exploration of Caves in the Derbyshire district.—Sir W. Boyd Dawkins (*Chairman*), Mr. G. A. Garfitt (*Secretary*), Mr. Leslie Armstrong, Mr. M. Burkitt, Mr. E. N. Fallaize, Dr. Favell, Miss D. A. E. Garrod, Mr. Wilfrid Jackson, Dr. R. R. Marett, Mr. L. S. Palmer, Mr. H. J. E. Peake. **£25**.

To investigate processes of Growth in Children, with a view to discovering Differences due to Race and Sex, and further to study Racial Differences in Women.—Sir A. Keith (*Chairman*), Prof. H. J. Fleure (*Secretary*), Mr. L. H. Dudley Buxton, Dr. A. Low, Prof. F. G. Parsons, Dr. F. C. Shrubsall. **£25**.

To report on proposals for an Anthropological and Archæological Bibliography, with power to co-operate with other bodies.—Dr. A. C. Haddon (*Chairman*), Mr. E. N. Fallaize (*Secretary*), Dr. T. Ashby, Mr. W. H. Barker, Mr. O. G. S. Crawford, Prof. H. J. Fleure, Prof. J. L. Myres, Mr. H. J. E. Peake, Dr. D. Randall-MacIver, Mr. T. Sheppard.

To report on the progress of Anthropological Teaching in the present century.—Dr. A. C. Haddon (*Chairman*), Prof. J. L. Myres (*Secretary*), Prof. H. J. Fleure, Dr. R. R. Marett, Prof. C. G. Seligman.

To investigate certain Physical Characters and the Family Histories of Triplet Children.—Dr. F. C. Shrubsall (*Chairman*), Mr. R. A. Fisher (*Secretary*), Miss R. M. Fleming, Dr. A. Low. **£20.**

To conduct explorations on early Neolithic Sites in Holderness.—Mr. H. J. E. Peake (*Chairman*), Mr. A. Leslie Armstrong (*Secretary*), Mr. M. Burkitt, Dr. R. V. Favell, Mr. G. A. Garfitt, Mr. Wilfrid Jackson, Mr. L. S. Palmer.

To investigate the antiquity and cultural relations of the ancient Copper Workings in the Katanga and Northern Rhodesia.—Mr. H. J. E. Peake (*Chairman*), Mr. E. N. Fallaize and Mr. G. A. Wainwright (*Secretaries*), Mr. H. Balfour, Mr. G. A. Garfitt, Dr. Randall-MacIver.

To co-operate in Ethnological and Geographical exploration on the Sepik River, New Guinea.—Mr. H. Balfour (*Chairman*), Mr. L. H. Dudley Buxton (*Secretary*), Mr. E. N. Fallaize, Dr. A. C. Haddon, Dr. R. R. Marett, Prof. C. G. Seligman.

To arrange for the publication of a new edition of 'Notes and Queries on Anthropology.'—Dr. A. C. Haddon (*Chairman*), Mr. E. N. Fallaize (*Secretary*), Mrs. Robert Aitken, Mrs. H. Balfour, Capt. T. A. Joyce, Prof. J. L. Myres, Prof. C. G. Seligman.

SECTION I.—PHYSIOLOGY.

The Cost of Cycling with varied rate and work.—Prof. J. S. Macdonald (*Chairman*), Dr. F. A. Duffield (*Secretary*). **£10**.

The Investigation of the Medullary Centres.—Prof. C. Lovatt Evans (*Chairman*), Dr. J. M. Duncan Scott (*Secretary*), Dr. H. H. Dale. **£20**.

Colour Vision, with particular reference to the classification of Colour-blindness.—Sir C. S. Sherrington (*Chairman*), Prof. H. E. Roaf (*Secretary*), Dr. Mary Collins, Dr. F. W. Edridge-Green.

SECTION J.—PSYCHOLOGY.

Vocational Tests.—Dr. C. S. Myers (*Chairman*), Dr. G. H. Miles (*Secretary*), Prof. C. Burt, Mr. F. M. Earle, Dr. Ll. Wynn Jones, Prof. T. H. Pear, Prof. C. Spearman, Mr. F. Watts. **£14**.

The place of Psychology in the Medical Curriculum.—Dr. W. Brown (*Chairman*), Dr. R. D. Gillespie (*Secretary*), Dr. C. H. Bond, Prof. E. P. Cathcart, Dr. Devine, Dr. J. A. Hadfield, Dr. Bernard Hart, Dr. D. K. Henderson, Mr. J. R. Lord, Dr. C. S. Myers, Prof. T. H. Pear, Dr. Ross.

The Character of a first-year University Course in Experimental Psychology.—Dr. J. Drever (*Chairman*), Dr. Mary Collins (*Secretary*), Mr. F. C. Bartlett, Mr. R. J. Bartlett, Prof. C. Burt, Dr. Shepherd Dawson, Prof. A. E. Heath, Dr. Ll. Wynn Jones, Prof. T. H. Pear.

SECTION K.—BOTANY.

To make investigations on the Marine Algæ attached to the salvaged German Warships at Scapa Flow.—Dr. A. B. Rendle (*Chairman*), Miss L. Lyle (*Secretary*), Mr. A. D. Cotton, Mr. A. Gepp. **£45**.

Investigations on the effect of duration and nature of Illumination on Growth and Flowering in *Arachis hypogæa* and *Voandzeia subterranea*.—Prof. W. Neilson Jones (*Chairman*), Dr. E. M. Delf (*Secretary*), Prof. V. H. Blackman. **£40.**

To consider the advisability of instituting a diploma in biology for students in training colleges.—Prof. F. O. Bower (*Chairman*), Prof. S. Mangham (*Secretary*), Miss A. Moodie, Mr. J. L. Sager, Miss E. H. Stevenson, Dr. Ethel N. Miles Thomas, Prof. J. Lloyd Williams.

SECTION L.—EDUCATIONAL SCIENCE.

To inquire into the Practicability of an International Auxiliary Language.—Dr. H. Forster Morley (*Chairman*), Dr. E. H. Tripp (*Secretary*), Mr. E. Bullough, Prof. F. G. Donnan, Prof. J. J. Findlay, Sir Richard Gregory, Sir W. B. Hardy, Dr. C. W. Kimmins, Sir E. Cooper Perry, Mr. Nowell Smith, Mr. A. E. Twentyman.

To consider the educational training of boys and girls in Secondary Schools for overseas life.—Rev. H. B. Gray (*Chairman*), Mr. C. E. Browne (*Secretary*), Major A. G. Church, Mr. H. W. Cousins, Dr. J. Vargas Eyre, Mr. G. H. Garrad, Sir R. A. Gregory, Mr. O. H. Latter, Miss E. H. McLean, Miss Rita Oldham, Mr. G. W. Olive, Miss Gladys Pott, Sir J. Russell, Rev. Canon H. Sewell, Mr. A. A. Somerville, Mrs. Gordon Wilson. **£10**.

The bearing on school work of recent views on formal training.—Prof. F. A. Cavenagh (*Chairman*), Prof. A. E. Heath (*Secretary*), Prof. R. L. Archer, Miss E. R. Conway, Prof. M. W. Keatinge, Mr. H. P. Sparling, Major E. R. Thomas, Prof. G. Thomson.

CORRESPONDING SOCIETIES.

Corresponding Societies Committee.—The President of the Association (*Chairman ex-officio*), Mr. T. Sheppard (*Vice-Chairman*), the General Secretaries, the General Treasurer, Dr. F. A. Bather, Sir Richard Gregory, Sir David Prain, Sir John Russell, Mr. Mark L. Sykes, Dr. C. Tierney ; with authority to co-opt representatives of Scientific Societies in the locality of the Annual Meeting.

THE CAIRD FUND.

An unconditional gift of £10,000 for research was made to the Association at the Dundee Meeting, 1912, by Mr. (afterwards Sir) J. K. Caird, LL.D., of Dundee.

The Council, in its report to the General Committee at the Birmingham Meeting, made certain recommendations as to the administration of this Fund. These recommendations were adopted, with the Report, by the General Committee at its meeting on September 10, 1913.

The allocations made from the Fund by the Council to September 1922 will be found stated in the *Report* for 1922, p. xxxi. Subsequent grants from the fund are incorporated in the lists of Research Committees.

In 1921-25 the Council authorised expenditure from accumulated income of the fund upon grants to Research Committees approved by the General Committee by way of supplementing sums available from the general funds of the Association, and in addition to grants ordinarily made by, or applied for from, the Council.

Sir J. K. Caird, on September 10, 1913, made a further gift of £1,000 to the Association, to be devoted to the study of Radio-activity. In 1920 the Council decided to devote the principal and interest of this gift at the rate of £250 per annum for five years to purposes of the research intended. The grants for the years ending March 24, 1922 and 1923, were made to Sir E. Rutherford, F.R.S. The grant for the year ending March 24, 1924, was made to Prof. F. Soddy, F.R.S. The grant for the year ending March 24, 1925, was divided between Messrs. C. T. R. Wilson (£100), J. Chadwick (£75), and A. S. Russell (£75). The grant for the year ending March 24, 1926, was divided between Mr. P. M. S. Blackett (£100), Dr. J. Chadwick (£100), and Dr. A. S. Russell (£50). For the year 1926-27 grants of £50 each were made to Messrs. Blackett, Chadwick and Russell, and balance remaining was brought into general funds and earmarked as available for a grant to any committee of the Association appointed in the future to undertake research in radio-activity.

RESOLUTIONS & RECOMMENDATIONS.

The following Resolutions and Recommendations were referred to the Council by the General Committee at Oxford for consideration, and, if desirable, for action (except where specified as approved for action):—

From Section A.

That the administrative officers of the Association be instructed to standardise the title of Section A in the form 'Mathematical and Physical Sciences.' (Approved for action.)

From Section A.

That the Council be requested to inquire into the possibility of republishing the reports of the Mathematical Tables Committee in collected form.

From Section D.

That, in view of the prohibitive duty required by H.M. Customs for the introduction into this country of Dr. Cushman Murphy's cinematograph film, the Council of the British Association be requested to take up the matter with a view to some distinction being made between scientific and commercial films in the matter of Customs charges.

From Section H.

That the British Association deplores the detriment to scientific investigation which results from certain details of the present scheme for the imposition of duties

on imported cinematograph films, and asks for such revision of the Customs regulations as will facilitate the introduction into this country of films dealing with purely scientific subjects not intended for commercial uses.

From the Conference of Delegates of Corresponding Societies.

That the Council be asked to represent to His Majesty's Government the serious detriment to scientific investigation and to the dissemination of scientific knowledge which results from the present restrictions on the importation into this country of cinematograph films recording scientific observations, intended for purposes of education and advanced study, and not for commercial purposes; and to ask for their amendment.

From Section K.

That the Sub-section of Forestry and the Section of Botany desire to emphasise the disastrous effects which follow the reckless destruction of forests on hill slopes and in the mountainous regions in the Tropics.

From Sections L and M.

That, with a view to the promotion of imperial interests overseas and the unlimited opportunities for land settlement, the Council be requested to draw public attention to the demand of the Dominions for the supply of young people of both sexes of good education, and to urge that adequate preparation for overseas life should be given in schools.

From the Conference of Delegates of Corresponding Societies.

That steps be taken, with the co-operation of local societies, to make systematic records of temporarily open geological sections, well-borings and the like.

From the General Committee.

The General Committee desires to express the cordial thanks of the Association to the President and Secretary of the South African Association for their telegram of good wishes, and especially for their early intimation of the desire of the South African Association that the British Association should hold its Meeting in South Africa in the year 1929; and hereby instructs the Council to make the necessary inquiries as to the date of the proposed Meeting, the necessary period of absence from this country, the probable expenses of the journey to members, and the financial provision which it is proposed to make for the Meeting; and in accordance with usual procedure to report to the next meeting of the General Committee.

A report of the Discussion on Educational Training for Overseas Life was ordered to be printed in extended form, with provision for the cost of reporting.

THE PRESIDENTIAL ADDRESS

BY

H.R.H. THE PRINCE OF WALES, K.G., D.C.L., F.R.S.,

PRESIDENT OF THE ASSOCIATION.

LADIES AND GENTLEMEN,

My first duty, as President of our great Association, must be to read to you the following message from His Majesty The King:—

> I am sensible of the distinction conferred upon my dear son, The Prince of Wales, in presiding at this year's meeting of the British Association for the Advancement of Science; for I realise that no Member of my Family has occupied this position since my grandfather was President in 1859. I cannot do better than repeat the assurances then made by the Prince Consort on behalf of Queen Victoria, and express my deep appreciation of the all-important and ceaseless labours in the cause of Science of those eminent men who enjoy the Membership of your world-renowned Society.

I propose on behalf of the Association to forward the following reply to this message:—

> The members of the British Association for the Advancement of Science assembled at Oxford humbly beg to express to Your Majesty their loyal appreciation of the patronage extended to the Association by your Father and Yourself, and of Your Majesties' repeated expressions of personal interest in its work.
>
> The Advancement of Science is the constant object of the British Association; to give a stronger impulse and more systematic direction to scientific inquiry, to promote the intercourse of those who cultivate science in different parts of the British Empire with one another and with foreign philosophers, to obtain a greater degree of national attention to the objects of science, by removing those disadvantages which impede its progress, for the well-being of Your Majesty's realm and the general good of mankind.

My second duty is to try and tell you—if this be possible—something which you do not know already. I must admit frankly that, for a long time, the prospect of attempting this has weighed on me heavily. For a man who, along with the great majority of his fellow-creatures, can lay claim to no intensive scientific training, it is no light responsibility to be called on to

address the annual gathering of the British Association. But, believe me, I do not intend to shirk that responsibility ; for it seems to me that only by discharging it as well as I possibly can, shall I be able to show you how highly I value the great honour you paid me, when you added my name to those of the distinguished men who have been your Presidents in past years.

At first sight, it might appear a hopeless task for anyone who knows nothing of Science to talk to you, who know everything about Science. But those who work in the scientific field will be the first to admit that no task is really hopeless, and, when I approached this one, I began to think I might perhaps find a few topics in which I could interest you. For, after all, Science is only another name for Knowledge, and any man who goes about the world with his eyes open cannot fail to acquire knowledge of some sort, which, if he can express it, must appeal to any audience.

To adapt one of our most familiar sayings, the onlooker can see a great deal of the game. And I, for instance, though I claim no insight into pure Science, can fairly claim an onlooker's experience of very many practical instances of Science as applied to the needs of our civilisation as we know it to-day. For some years past, in war and in peace, I have been privileged to have countless opportunities of examining, at close quarters, the concrete results of such applied science. In things military and naval, in factories, workshops, mines, railroads, in contact with the everyday problems of education, health, land-settlement, agriculture, transport or housing—in all such varied departments of human life, it has been borne in on me more and more that if civilisation is to go on, it can only progress along a road of which the foundations have been laid by scientific thought and research. More than that, I have come to realise that the future solution of practically all of the domestic and social difficulties with which we have to grapple nowadays will only be found by scientific methods.

It is from this experience, and with the convictions it has brought, that I should like to-night to tell you something of my general impressions of the bearing of Scientific Research on the daily life of the community ; and to show how that relationship can be developed by the mutual co-operation of scientific workers and the State. I cannot better embark on this attempt than by quoting to you the words of my distinguished predecessor, though without the hope that what follows will maintain the high standard which he set in his Presidential Address at the last meeting.

Professor Lamb, on that occasion, expressed confidence that the efforts of scientific workers ' have their place, not a mean one, in human activities, and that they tend, if often in unimagined ways, to increase the intellectual

and the material and even the æsthetic possessions of the world. And in that assurance (he continued) we may rejoice that Science has never been so widely and so enthusiastically cultivated as at the present time, with so complete sincerity, or (we may claim) with more brilliant success.' This claim, by no means exaggerated, invites reflection upon the intimate association of the results of scientific research with the daily lives and affairs of every one of us. And it is a good thing to reflect upon this, even for those who have no sort of direct contact with scientific research, if only because the doing so may dispel an attitude towards Science, which personifies it somewhat as the ancients personified the powers of darkness, and invests it with some of their sinister attributes. Such an attitude of mind is fortunately less common than it used to be. Professor Lamb, in the address already quoted, referred to a certain feeling of dumb hostility toward Science and its works, which still survives. No doubt it does; but at least it has ceased to be vocal, as it was in the earlier days of the Association. It became loud (for example) at two of the meetings in this very place. The later of these two occasions was the Oxford Meeting in 1860, and the field of battle was the section of Botany and Zoology, in which the theories put forward in Darwin's *Origin of Species* were debated, in a manner which has passed into history, between Wilberforce, Bishop of Oxford, on the one hand, and Huxley and Hooker on the other.

The earlier occasion, however, more appropriately illustrates, by contrast, the modern realisation of our debt to Science.

The second meeting of the Association, in 1832, took place in Oxford. The University was not, at that time, without distinguished cultivators of Science. The invitation to Oxford came from Charles Daubeny, who combined the professorships of chemistry, botany, and rural economy, and the president was William Buckland, then Canon of Christ Church and professor of mineralogy and geology. But a strong body of opinion resented the recognition of Science by the University when carried to the extent of conferring honorary degrees upon four of the distinguished visitors. The famous Keble, moved for once to anger, referred to those who were thus honoured as a 'hodge-podge of philosophers.' Their names were David Brewster, Robert Brown, John Dalton, and Michael Faraday. Each of these men has left in the history of his own special branches of Science an outstanding memorial. Brewster's researches into optics were his greatest scientific achievement; to our own gratitude he has an especial claim as the leader among the founders of our Association. Brown's services to botany were unsurpassed; perhaps that of widest appeal is his very

thorough investigation of the flora of the coastlands of Australia, made during the voyage on which he accompanied Flinders in 1810-14; an early example of what may be termed imperial research. Dalton's name is identified for ever with the atomic theory, and he placed meteorology on a scientific footing. Faraday's labours provide one of the most wonderful examples of scientific research leading to enormous industrial development. Upon his discovery of benzene and its structure the great chemical industries of to-day are largely based, including, in particular, the dyeing industries. Still wider applications have followed upon his discovery of the laws of electrolysis and of the mechanical generation of electricity. It has been said, and with reason, that the two million workers in this country alone who are dependent upon electrical industries are living on the brain of Faraday; but to his discoveries in the first instance many millions more owe the uses of electricity in lighting, traction, communication, and industrial power. Oxford, then, was not dishonoured in the hodge-podge of philosophers whom she recognised in 1832. Nor will she recall with any disfavour the singularly doubtful compliment paid her on that occasion by another distinguished visitor, in whose mind the opposition must have rankled; the University, he said, had prolonged her existence for a hundred years by the kind reception he and his fellows had received. The Association will scarcely make that claim to-day. But its visiting members will have ample opportunity to learn how, through her museums and laboratories, Oxford, within the hundred years thus tolerantly allotted to her, has kept pace with the scientific development of the period. It need surely be no matter for regret if Science has worked for and is taking a place, not only in the university but in the schools, complementary with that occupied by the humanities. For complementary these two branches of learning must ultimately be. All the greatest exponents of scientific learning have been men of attainment also in letters.

The services rendered to mankind by the labours of outstanding figures in Science, such as Faraday, or Kelvin, or Pasteur, or Lister, are matters of too common knowledge to need insisting upon in this place. What is perhaps less generally appreciated is the extent to which, through the efforts of very numerous workers, the results of scientific research have been brought to bear upon many of the most pressing domestic and industrial problems of the day, and that the co-operation between the laboratory and the State (which means the community) has been greatly strengthened of recent years. The British Association has always supported such co-operation. One of its principal aims, as stated by its founders and main-

tained ever since, is 'to obtain more general attention for the objects of Science and the removal of any disadvantages of a public kind which impede its progress.' In an article contributed by Brewster to the 'Quarterly Review' in 1830, he asserted frankly that 'the sciences of England' were 'in a wretched state of depression, and their decline is mainly owing to the ignorance and supineness of the Government' as well as to various other causes which he detailed. The same theme (if less forcibly stated) recurs in some of the earlier addresses from the chair of the Association: the Prince Consort, for example, as President in 1859, thus indicates his view of the situation at that time—'We may be justified in hoping,' he said, 'that by the gradual diffusion of Science, and its increasing recognition as a principal part of our national education, the public in general, no less than the legislature and the State, will more and more recognise the claims of Science to their attention; so that it may no longer require the begging-box, but speak to the State, like a favoured child to its parent, sure of his parental solicitude for its welfare; that the State will recognise in Science one of its elements of strength and prosperity, to foster which the clearest dictates of self-interest demand.'

It may be fairly said that the position foreshadowed in those words is now, in a large measure, attained. The progress towards it was visible, if slow, down to the end of the last century; but the beginning of a new era was then marked by the establishment of the National Physical Laboratory. This was at first set up in Kew Observatory, a building which, as a laboratory for magnetic and meteorological observations, and for the standardising of instruments, owed its maintenance to the British Association for thirty years from 1841, when, as a royal observatory, the Government decided to dismantle it. The building proved incapable of extension to accommodate the whole of the work, and in 1900 Bushy House, Teddington, was placed at the disposal of the laboratory by the Crown. The laboratory, at its inception, was divided into departments dealing with physics, engineering and chemistry, and it possesses also the famous William Froude experimental ship tank. The investigations with which it has been so largely concerned—the testing and standardisation of machines, materials, and scientific instruments, researches into methods of measurement with the utmost accuracy, work on scale-models of ships, and the like—while of the first importance to Government Departments concerned with such applications of science, have also achieved many valuable results for industry in improving standard qualities, in indicating scientific methods applicable throughout a variety of manu-

factures, and thus in bringing about an improvement in the quality of their output for the benefit of consumers—which is to say, ourselves.

In historical sequence among the events which have strengthened interaction between Science and the State, there follows the establishment of the Development Commission in 1908. Until that date the only agency for agricultural research in Great Britain was the classical experimental station at Rothamsted, a private benefaction; and the expenditure of the State on this prime factor in national economy was trifling. Since 1908 the Rothamsted station has been expanded to cover the whole field of nutrition and disease in the plant, while other institutes have been founded to deal with other aspects of agriculture such as plant breeding, the nutrition and diseases of animals, agricultural machinery and the economics of the industry. Not only are these institutes providing knowledge for our own farmers, but they form the training-ground for agricultural experts required by the Dominions, India, and the Crown Colonies, which need no longer look abroad for their advisers. At the plant-breeding institute at Cambridge, Sir Rowland Biffen has provided several new wheats, of which two are generally grown throughout the country; the extra yield and value of these wheats must already have more than repaid the whole expenditure on agricultural research since the institute was founded. Among other examples of the value of research there may be mentioned the discovery of a variety of potato immune from the ineradicable wart disease, which a few years ago threatened the principal growing districts. The clearing up of the confusion into which commercial stocks of fruit trees had fallen has ensured that growers may plant orchards upon uniform stocks suitable to the soil and climate. And among the most important inquiries are those into the production and cleansing of milk, which have resulted in an entire reform of rationing, increasing the yield of each cow by one to two hundred gallons a year, and in freeing milk from the risk of contamination with disease.

Research into fisheries (which are administratively associated with agriculture) has become a matter of necessity in the light of evidence that even the vast resources of the sea have their limit, and can be injured if they are not exploited with due care and knowledge. Great Britain, acting in co-operation with the other nations who share with us the northern seas, has accomplished much in ascertaining the causes of the fluctuating herring supply, and has contributed notably to the study of the methods by which the stocks of plaice can be maintained. Research again is active in finding methods by which we can mitigate one of the

consequences of our dense population—the pollution of our rivers and estuaries, and a method has been found whereby great supplies of shell-fish that had been condemned are once more available as food. Some of my hearers will know, too, of the remarkable results obtained from the scientific study of the habits of the salmon. Though fishing has been described as 'a fool at one end of a string and a worm at the other,' the subject is not without its personal interest, I believe, to many learned men.

Reverting to the historical sequence, it is appropriate to recall, with gratitude for its labours, the constitution of the Medical Research Committee in 1913, under the Insurance Act of 1911: this has since (in 1919) been transferred to a committee of the Privy Council under the name of the Medical Research Council, and its funds are directly voted by Parliament instead of being drawn from the contributions made by or on behalf of insured persons.

Research alone could provide the knowledge on which must be based all wise and effective legislation or administrative action in the interests of the nation's health. Yet until 1913 the State had played at best a subsidiary part in the organisation of such research and the provision of its material support. Under the new conditions the State is actively concerned with the promotion and co-ordination of medical research towards conquest of those infirmities with which ignorance has afflicted humanity. A few only may be mentioned, which have rightly appealed to wide public interest. Insulin, a gift to science and to humanity from young enterprise and enthusiasm in the Dominion of Canada, is not only saving lives that were threatened, and restoring almost to normal health and enjoyment many that were crippled by weakness and restriction, but, as a tool of investigation, is shaping new knowledge that will influence all our ideas of the functions of the body, in health or disease. The discovery of the vitamins, those still mysterious and minute constituents of a natural diet, has brought understanding of various defects of health and of development, created for us largely by the blindness of civilisation to dangers accompanying its progress, dangers which science can avert. Closely linked with the discovery has been the more recent development of knowledge concerning the need of sunlight for health, in man and his fellow animals as in plants. We know now that crippling deformity appears in the growing child unless he receives his proper share of the vitalising rays of the sun, either directly or through the presence in natural foods of vitamins which these rays have produced. Sunlight, or its

artificial equivalents, have some importance already in the treatment of disease; but a realisation of its significance for health has a much greater importance in preventive hygiene. There can surely be no plainer duty, for a State charged with the health of an industrial civilisation, than to promote with all its resources the search for such knowledge as this, as well as to provide for its application when obtained.

Among diseases which painfully affect the popular imagination, cancer has an evil pre-eminence, largely on account of its mysterious, and therefore seemingly inevitable nature. For many years past a volume of investigation, supported by private benefactions and organised charity, has patiently accumulated knowledge of the beginnings of cancer and the conditions of its growth. Now, at length, there are signs of more rapid progress towards a penetration of its secret. Patience and caution are as necessary as ever; a new and exacting technique is still in development; but there is a new spirit of hope and enthusiasm. And it is reassuring to know that in this, as in other directions, the State is giving its direct support to investigation, and co-operating with the foundations due to private generosity.

Looking backward a dozen years or so, one may say that Science was definitely, by that time, a working part of the machinery of the State, though, as we see now, not a part working at full power. The Great War caused a broadening, so to speak, of the scientific horizon for men of science themselves in some measure, but for the layman in a measure far greater. We all were brought to recognise the applications of Science as adding, it may be, in certain respects to the distresses of warfare; but also as immensely alleviating the sufferings caused by it, and as indicating many methods of strengthening the arts of defence—some of which methods are no less valuable in strengthening the arts of peace. The creation of the Government Department of Scientific and Industrial Research was an act which falls, historically, within the period of the war; but as an outstanding incident in the scientific advancement of national affairs, it certainly is not to be regarded as merely a war measure; it was once described as a near relative of 'Dora,' but that was a mistake. Nevertheless, by an odd freak of history, it needed the whole period of a century between one great war-time and the next—between the Napoleonic and the World Wars—to mature the conception of a State department of scientific research. Some idea of this kind was clearly present in the mind of Brewster, and certain of his contemporaries, concurrently with his idea of the foundation of our own Association in 1831; and later (in 1850)

when he addressed the Association from the chair, he claimed a strong advance in scientific and public opinion toward his views. Five years later a concrete proposal for the creation of a Board of Science, possessing 'at once authority and knowledge,' was put forward by the Parliamentary Committee of this Association (a committee no longer existing); but our Council at the time considered that the proposal had 'yet to receive sanction from public opinion, and more especially from the opinion of men of science themselves.' It was not, in fact, entirely owing to lack of prevision on the side of successive Governments that the developments which have been outlined were so long delayed. There was an element of mutual distrust between Science and the State—now, it may happily be believed, almost if not quite wholly removed. A strong body of scientific opinion was avowedly afraid (as Sir George Airy phrased it) of 'organisations of any kind dependent on the State.' It is to be hoped that modern developments have removed that fear. The progress of Science cannot be kept wholly within training-walls, and no one wants to try to keep it so. The waters of a river may be guided artificially to do the work of irrigation; but not at their sources, nor yet where, at the last, they percolate the soil. The guidance of scientific research, in its inception, lies with the genius of the individual; its results for the future may lie far beyond the realisation even of the scientific workers themselves. The Oxford Meeting of the Association in 1894 supplies a simple example of this. There was a discussion on flight, in the Section of Mathematics and Physics, opened by Hiram Maxim; and no less a leader in science than Kelvin afterwards described Maxim's own flying machine as a child's perambulator with a sunshade magnified eight times. Yet it was not many years before research in aeronautics had become the care of the State as well as of the individual; and the work carried out before 1914 under (what is now) the Aeronautical Research Committee led on to our wonderful development of aircraft during the war.

A recent report of the Committee of the Privy Council for Scientific and Industrial Research shows that under the Department there are eleven research boards, some of which direct the work of committees to the number of three dozen in all. These boards co-ordinate and govern researches in chemistry, fabrics, engineering, and physics, radio, building, food-investigation, forest-products, and fuel; and to these are to be added the board of the Geological Survey and the executive committee of the National Physical Laboratory. Under the general supervision of the Advisory Council there are upwards of twenty industrial research associa-

tions, formed in alliance with the same number of the principal industries of the country, for the purposes of scientific investigations connected with those industries. No attempt can be made here to review the whole field of work of these various bodies ; but a few examples may be chosen for the purpose of pointing out what may be called their homely application. First, then, as to the building of the home. The Building Research Board was created in 1920, and in 1925, at the request of the Ministry of Health, considerably extended its activities. Researches are concerned with the study of materials from the chemical and geological aspects, their strength, weathering, moisture condensation on wall coverings, acoustics, and various other problems ; these inquiries, together with the collection and supply of information both by publication and through an intelligence bureau, represent (as the report states) ' an attempt to create a real science of building, to explain and supplement the traditional knowledge possessed to-day in the industry.' It can scarcely be questioned that industrial Britain inherits a legacy of discomfort in the housing of its workers, with all which that implies, dating from a period when the building of the home lacked scientific as well as æsthetic guidance. We need that guidance no less to-day, when the saving of labour is one of the main objectives of the ' ideal home ' and its fitments.

Next, a further word as to our food supplies. The Food Investigation Board directs committees concerned with meat and fish preservation, fruit and vegetables, oils and fats, and canned foods. There is also a committee for engineering problems associated with the investigations ; conditions of storage have been investigated on ships between this country and Australia, and problems of heat-conductivity at the National Physical Laboratory, while chemical substances suitable for refrigerants have been studied at the Engineering School here in Oxford. At Cambridge a low-temperature research station has been established on ground given by the University, and is working in co-operation with the University bio-chemical, botanical, agricultural, and other laboratories. As for the investigations upon fruit and vegetables, the report may again be quoted, for it illustrates in a sentence something approaching the ideal of scientific co-operation brought to bear upon one particular home necessity, and (what is more) upon a particular and important branch of Imperial commerce. ' There is (it says) a closely knit scheme of work, which rests, on the one hand, in university schools of botany, and, on the other, in commercial stores scattered all over the country, where accurate records of results and conditions have been kept, and extends to the conditions

of transport by ship, and overseas so far even as the Australasian orchards.* Other directions of research which touch upon commonplaces of our daily life are those concerned with fuel, with illumination, with the deterioration of fabrics and the fading of coloured stuffs, and—perhaps most homely example of all—with the application of scientific methods in the laundry industry. This will be good news to those of us who may have suffered, or may even be suffering to-night, from the torture of a collar which comes back from the wash with an edge like a surgical saw. It must be clearly understood that the few instances mentioned represent only a small fraction of the present activities of Science in co-operation with the State. And expressed as they are here expressed, they may appear to wear an aspect even of triviality, because they deal with common things. But it is precisely because they do deal with common things that they are not trivial. There may be matter for amusement in the fact that Science is concerning itself with the contents of the clothes-basket; but there is also matter for congratulation, and there may, in the future, be matter for sincere gratitude. Scientific research, properly applied and carried out, is never wasted. It may prove that a thing can be done, or that it can not be done; but even the proof of a negative may save the waste of further effort.

This attitude of the State toward Science makes for an easing of the paths for the advancement of science in many directions; it marks a definite step in human progress, taken after long hesitation, but in itself new; and because it is new, we may believe with some reason that we live, not merely in an age of science, but at the beginning of it. The movement for co-operation which we have been discussing is not confined to this country. It has borne fine fruit already in other lands; and in particular it is active in our own Dominions. The Indian Empire stands in a somewhat different category from these: there is here a tradition, so to say, for the application of science in its government, and the scientific results of its census investigations, its surveys, its agricultural forestry, and other administrative departments have long been famous. This is not to imply that brilliant scientific work has been wanting in the Dominions—far from it—but the co-operative movements with their governments have followed that in this country and with a laudable promptitude. The trend of developments following upon all these movements has been similar broadly speaking; it is sought to take a comprehensive survey of the natural resources and industrial opportunities of each Dominion, to explore the means by which Science may be best applied

to their exploitation, to provide, whether in State institutions or in university and other laboratories, for the pursuit of the necessary researches, to co-ordinate the work, and to ensure the dissemination of knowledge acquired. The nature of the researches themselves is conditioned to a large extent (though by no means wholly) by geographical circumstances in the respective territories: agricultural, pastoral, and forestry problems, for example, are not identical in all of them, and that very fact adds to the interest and value of co-ordinating the results of research work throughout the Empire. While problems may differ, solutions may point to a common end. Nothing but good can follow from personal contact between scientific workers in different parts of the Empire. Nothing but good can follow from their researches if they add, as gradually they must add, to the wider knowledge of the Empire not only among the workers themselves, but ultimately among the whole body of informed Imperial citizenship; not only in the overseas territories, but here at home. For us at home the Empire is worth knowing. Our knowledge of it begins with the school lessons in geography and history—or should do so; no doubt the ideal here is yet to be attained. Such knowledge may become later of vital importance to those who wish to join the stream of overseas migration. The British Association, in pursuit of its policy of obtaining from time to time 'reports on the state of science' in one department or another, has recently, through a committee of the Section of Educational Science, been collecting evidence as to the facilities existing in our schools for training boys and girls for life overseas. In the crowded curriculum of most schools these facilities, at any rate in their particular Imperial application, are not conspicuous. Yet any labour which time allows us to spend, whether in school days or after them, upon the advancement of scientific knowledge of the Empire, of the means and manner and environment of life in its component territories, must be well spent. The British Association has played its part in this advancement since, in 1884, it admitted the principle and established the practice of holding occasional meetings overseas. Those of our members who travelled from this country to take part in these meetings have had peculiar opportunities to meet and discuss each his own scientific problems with fellow-workers in the Dominions—and it should be added with particular reference to those meetings which have been held in Canada that they have provided almost unique opportunities for personal contact between British workers in science and their American colleagues. Our travelling members have been able to see how science is cultivated in the universities of the

Dominions and in many other institutions; they have gained first-hand acquaintance with the special problems of one territory and another; and when they have returned home they have talked—as anyone who travels the Empire is impelled to talk. I have myself been guilty of giving way to this impulse once in a while. Opportunities for travel are none too common for most of us, but most of us can at least cast our minds back to the exhibition at Wembley. Science herself, as an exhibitor, took a place there befitting her natural modesty. The scientific exhibit arranged by the Royal Society, admirable as it was, was confined to two rooms of the Government Pavilion. But was not a very large proportion of the entire exhibition, in point of fact, an exhibition of applied science?

It is impossible in the Imperial connection to overstate the case for Science. Sir William Huggins, in his Presidential Address to the Royal Society in 1901, said that 'assuredly not only the prosperity, but even the existence of this Empire will be found to depend upon the more complete application of scientific knowledge and methods to every department of industrial and national activity.' To-day we see that application in much fuller progress than when Huggins spoke only a quarter of a century ago, and already we know how truly he prophesied.

It is not for a moment to be supposed, because the State has come to take a more active and practical interest in scientific research, that there is therefore any occasion for the lessening of interest on the part of societies and individuals. The State interest involves that other interest, and invites it. It can never become the exclusive function of the State to aid the individual research worker. The State may, and does, co-operate in aiding him, as for instance through the universities and the Royal Society. Nevertheless, there are whole departments of research which do not come within the range of public assistance, but are no less valuable because they do not. Therefore the support of science remains the concern of our scientific societies, educational institutions, industrial organisations, and private benefactors, no less than it ever did; nay, the very fact that the State has lent its aid should encourage them to continue their aid and to reinforce it—indeed, there is satisfactory evidence that this actually happens. One example will suffice which indicates, incidentally, that from the purely materialistic point of view scientific research is not a luxury; for the community it is probably the cheapest possible form of investment. The Government's fuel-research station has not yet proved the commercial possibility of the low-temperature treatment of coal which would result in the more economical production of smokeless

fuel, oils, and gas ; but in attempting this difficult task it has already, by results unforeseen when the task was undertaken, shown at any rate the possibility of economies for the State and for some of its major industries which are well in excess of the cost of the research itself.

There are parallels in many respects, as has been often pointed out and as often forgotten, between the periods of our history following the Napoleonic Wars and the Great War. The application of science in industry and daily life received impetus in the earlier of these periods in such directions as the introduction of steam motive-power ; it is receiving it now, as it has been attempted here to show. The auspices now are more favourable. Science is more powerful. Men more adequately and more generally recognise its power, and therein should lie a certain ethical value for it as offering a new point of view, in the manifold interest of which all can share. Should not the application of science, for instance, offer a new field for community of interest, not only between one industrial organisation and another, but within the whole body of workers in any single organisation ? But in order that the community may fully realise all that it owes, and all that it might owe, to the advancement of science, the channels of communication between research and the public mind have to be kept clear, maintained and widened. The non-scientific public is accustomed to view science as it might view a volcano ; prepared for the eruption of some new discovery from time to time, but accepting the effects of the eruption without realising the processes which led up to it during the preceding period of quiescence. The period of preparation by research before science can offer the world some new benefit may be long, but the scientific machine is always running quietly in the laboratory. There is an example ready to our hands. We recall the introduction of wireless telegraphy and telephony as a scientific gift of quite recent years. Do we all realise that it was here in Oxford, at the Meeting of the British Association so long ago as 1894, that the first public demonstration of wireless signalling by means of electro-magnetic waves was given by Sir Oliver Lodge ? It was the work of science to develop the methods then demonstrated until they have been brought to their present marvellous uses. On the other hand it is often the case, whether in industrial or agricultural, domestic or whatever application, that science has knowledge at command, awaiting use, long before mankind can be brought actually to apply it. Though we have quickened, we are not yet so quick in the uptake of the results of applied scientific research as, for instance, some of our commercial competitors. The public support of scientific research, upon

all these grounds, should be accorded freely, with understanding, and with patience.

This brings me, Ladies and Gentlemen, to the close of what I have to say to you this evening. From my opening remarks, you will have gathered that I looked on you as an extremely formidable audience. That was when I only knew you, so to speak, on paper. Now that I have met some of you face to face—and hope to meet others in the Town Hall in a few minutes—I can only say that, if the Presidential Address has not the traditional weight of knowledge behind it, no President in the history of the Association has ever received a more kindly and sympathetic welcome than you have given me to-night. I am deeply grateful for it.

One more duty remains to me—a duty to our hosts and to our guests. The University and the City of Oxford have received us all with a high hospitality worthy of this town, to which all who have known it in the past always return with delight, and which never fails to throw its spell on those who see it for the first time. Their friendly reception has made it possible for those who have worked so hard at the organisation of this meeting to bring it to the successful culmination which it promises to attain. Not the least successful feature of it is the large number of distinguished guests whom it has attracted from overseas. To all of these I wish to offer a most cordial welcome, with the sincere hope that they may always carry with them, as I shall myself, the most pleasant recollections of a very memorable gathering.

SECTIONAL ADDRESSES.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCES.

THE ANALYSIS OF LINE SPECTRA.

ADDRESS BY

PROFESSOR A. FOWLER, F.R.S.,

PRESIDENT OF THE SECTION.

Although spectroscopy formed the subject of Prof. McLennan's Presidential Address to the Section so recently as 1923, I feel that no apology is needed for returning to this subject on the present occasion. In the three years which have elapsed spectroscopy has, in fact, made immense progress in several directions. It has now become one of the most important developments of physical research, and seems likely in the near future to make contributions of a fundamental character to other branches of science. Its development from a subordinate and little-known adjunct of chemistry to the commanding position which it now occupies forms a most interesting chapter in the history of science, and, as one who has long been associated with spectroscopic research on the experimental side, I may perhaps best approach the modern viewpoint by recalling some of the more important stages in its progress.

Rather more than sixty years ago, when the spectroscope became an effective instrument of scientific research through the work of Kirchhoff and Bunsen, it was regarded essentially as providing a new and powerful method of chemical analysis. It soon had brilliant results to show in the discovery of a number of new elements, but this kind of discovery could not go on indefinitely, and the interest of chemists as a body in spectrum analysis would appear to have declined rather rapidly. In contrast with the present outlook in spectroscopy, it is interesting to recall that what was then regarded as one of the greatest attributes of the spectroscopic test was its extreme delicacy, so that Kirchhoff and Bunsen, for example, were able to show that one three-millionth of a milligram of sodium could be recognised with certainty. Spectrum analysis, however, as was soon realised, was not so simple a matter as it first appeared, and called for so much study that its pursuit was mainly left in the hands of a small band of specialists.

The introduction of the spectroscope into astronomy, which also followed almost immediately the discovery by Kirchhoff in 1859 of the nature of the dark lines of the solar spectrum, gave another interest to spectroscopic investigations, which has continued to grow without a break. Some of the most important developments of spectroscopy have, in fact, been closely associated with attempts to interpret the spectra of celestial bodies. It was not long before Huggins and Lockyer, who were prominent among the pioneer workers in this field, realised that laboratory experiments must go hand in hand with observations of the heavenly bodies,

and a spectroscopic laboratory came to be regarded by them as an indispensable adjunct to an astrophysical observatory. The methods of physical laboratories were freely utilised in these investigations and the chemical interpretation of celestial spectra made rapid progress. The introduction of photographic methods of observation by Huggins led almost at once to the discovery of new lines apparently belonging to hydrogen in the spectra of Sirius and other white stars, which were subsequently of great value in the establishment of Balmer's law of the hydrogen spectrum. Perhaps the greatest contribution of early astrophysics to our stock of knowledge, however, was that which so clearly pointed to the essential identity of matter throughout the universe.

With the discovery that the spectra of certain elements were modified by varying the character of the exciting source, chemical analysis of the sun and stars was supplemented and eventually overshadowed by investigations of the physical conditions which prevail in those bodies. The sun and stars thus came to be regarded as natural experiments on generally similar masses of matter at various high temperatures—experiments ready prepared for observation and always in operation. Thus many laboratory researches were directly instigated by astrophysical observations. To take one instance, the fragmentary observations by Lockyer and by Liveing and Dewar of what were afterwards called *enhanced lines* were extended and systematised through an attempt by Lockyer, in which I myself took part, to interpret the spectrum of the solar chromosphere as photographed during the total eclipses of the sun in 1893 and 1896. The immediate result was an important correlation of the changes in the laboratory spectra of the elements with the succession of types in stellar spectra,[1] from which it appeared that enhanced lines were especially characteristic of stars which, on other grounds, were believed to be hotter than the sun. These investigations laid the foundations for a true interpretation of the spectra of the hotter stars, and led to the more extended studies of enhanced lines which have proved of such great importance in the development of the theory of the origin of spectra and the structure of atoms.

On the other hand, it may be remarked, astrophysics owes much to laboratory experiments which were undertaken without regard to the sun and stars. One of the most notable examples is Zeeman's famous discovery of the splitting of spectrum lines when the source is placed in a magnetic field—a discovery which was afterwards applied with such brilliant success by Hale to the detection of the magnetic fields in sunspots and of the general magnetic field of the sun.

In one way or another the spectrum has thus become much more than a key to chemical composition; it has become also a key to the physical conditions under which the corresponding radiation is excited; and, as some of the earlier workers clearly anticipated, a key to the problem of atomic and molecular structure.

The remarkable developments of modern spectroscopy in the direction of atomic physics have resulted from discoveries relating to regularities in spectra. Such regularities were suspected as long ago as 1869, and were actually revealed about ten years later by the admirable experimental

[1] Lockyer, *Roy. Soc. Proc.*, vol. 60, p. 475 (1897).

work of Liveing and Dewar and of Hartley, who appear, however, to have made no very serious attempts to represent their results in any systematic way. The first important step in this direction was the formulation by Balmer in 1885 of the law of the line spectrum of hydrogen, in which the four laboratory and ten stellar lines then known were represented by a very simple formula involving a sequence of integers. The idea of a 'series' of spectrum lines which originated in this way was shortly afterwards extended by Kayser and Runge, and by Rydberg, to the regularities in other comparatively simple spectra, with results which are now generally familiar. Three types of series—the so-called Principal, Sharp and Diffuse series[2]—were recognised, and while some of the series consisted of single lines, others consisted of doublets or triplets.[3]

The foundations for subsequent developments were firmly laid by the classical work of Rydberg, in which the interrelationships of the different series in the spectrum of a single element were clearly formulated. Rydberg also suspected that other lines might be brought into the series relationships, but it is to Ritz that we owe the first clear statement of the 'combination principle' and the emphasis which it gives to the significance of spectroscopic 'terms' as distinct from spectrum lines.

In the representation of series spectra the wave-number of a line always appears as the difference of two terms, and a series of lines appears as a regular succession of differences between a limiting term and a sequence of terms, the limit itself being a term of another sequence. Thus the entire line spectrum of hydrogen, including the ultra-violet and infra-red series, as well as the Balmer series, is represented by differences between terms of the form R/n^2, where R is the Rydberg constant ($=109{,}678$ in wave-number) and n takes successive integral values beginning with 1 and theoretically extending to infinity. Other spectra are more complex, but lines in these also were found to be represented by differences between terms of the form $R/(n^*)^2$, where n^* is not restricted to integral values and has different values for the different sequences of terms included in a spectrum; n^* increases, however, approximately by unity from one term to the next in each sequence.

Much of the early work on series regularities in spectra is summarised in the now well-known symbolic representation of a series system, namely,

Principal series	$1\,S - mP_i$
Sharp series	$1\,P_i - mS$
Diffuse series	$1\,P_i - mD_i$
Fundamental series	$2\,D_i - mF_i$

where 1 S, for example, represents an individual term, and mS a sequence of terms of S type. The S terms are always single, but the others are complex in all but singlet systems; so that $i=1$ for singlets; 1, 2 for doublets; and 1, 2, 3 for triplets (in the older numeration). A sequence of terms may be represented by an approximate formula such as that of Hicks, in the form $R/[m+\mu+\alpha/m]^2$, where R is the Rydberg constant, m a serial number, and μ and α constants (usually proper fractions) to be determined from the observed lines. The possible combinations of terms

[2] The 'Fundamental Series' was added later.

[3] See Fowler's 'Report on Series.'

in the production of lines are restricted in accordance with selection rules which have since been extended to more complex spectra, as will appear later.

From the theoretical point of view the terms have a more direct physical significance than the actual lines, and it is therefore important to determine them with the greatest possible accuracy. Actual values of the terms can be determined only from spectra in which series have been identified. The calculated limit for one of the series then gives one of the terms of a system, and all the rest follow from the interrelations by subtracting the observed wave-numbers of lines from the limits of the series to which they belong. Since the same terms may enter into several combinations, it is obvious that the representation of a spectrum by terms is a great simplification.

It should be understood that these studies of the structure of spectra were pursued with the clear conviction that they would ultimately reveal the secrets of atomic structure, and the analysis of spectra, as distinct from spectrum analysis, gradually became one of the principal objects of spectroscopic research.

Notwithstanding the absence of a guiding theory of the origin of spectra, experimental spectroscopy continued to attract a number of workers, who approached the subject from various points of view and accumulated a vast store of observational data.

With the advent of Bohr's theory of spectra in 1913, spectroscopy entered on a new phase of activity. The theory and its immediate explanation of the spectra of hydrogen and ionised helium are now so well known as to call for little more than mention. Adopting the Rutherford conception of a neutral atom (namely, a positively charged nucleus with sufficient electrons in orbital motion around it to neutralise the positive charge of the nucleus) and restricting the possible orbits by quantum considerations, Bohr was able to extend the theory to account in a general way for the series spectra of other elements. Spectroscopic terms were translated by the theory into 'energy levels' of the atom, so that a spectrum line is considered to represent the energy emitted by an excited atom when it passes from a non-radiating state of a certain energy to another of lesser energy. The terms are, in fact, proportional to the energies of the corresponding 'stationary' states.

The spectrum of a neutral atom is supposed to be generated, one line at a time, by the transitions from one possible orbit to another of the most loosely bound of the outer electrons (the 'series electron' or 'light electron'), while the whole spectrum represents the integration of the various transitions taking place in different atoms. In partial justification of this view, one might point to the spectra of the alkali metals, which are very closely similar, and thus indicate that the general type of spectrum is independent of the total number of electrons present. The influence of the underlying electrons, or of the nuclear charge, however, becomes apparent in the increase of doublet separations with atomic number, and in the displacement of corresponding lines to different parts of the spectrum.

The theory in its first form also gave a definite significance to the enhanced lines occurring in the spectra of other elements besides helium.

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Lockyer's hypothesis that such lines originated in dissociated atoms—*i.e.* atoms split up into parts of comparable size, constituting 'proto-elements'—was in fact replaced in the new theory by the conception that the first stage of dissociation is the breaking up of a neutral atom into an ionised atom and an electron. An excited atom in which the series electron does not pass outside the sphere of influence of the nuclear charge remains neutral as a whole, and the spectrum is that of the neutral atom, having the Rydberg number R for the series constant. If the most loosely bound electron be driven out of the atom, and the next most loosely bound one transferred from its normal position to larger orbits by the exciting agency, the spectrum generated by the return of the second electron will be that of the ionised atom. This process could obviously be supposed to be repeated, so that spectra originating in doubly- or multiply-ionised atoms might be considered possible. The theory predicted that such spectra would be characterised by series systems for which the series constant would be 4 R, 9 R, 16 R, and so on, for atoms at successive stages of ionisation. The spectrum of ionised helium, which had previously been obtained without its identification as such,[4] had indeed already contributed very materially to the formulation of the new theory.

Bohr's theory proved a great stimulus to experimental spectroscopy as well as to theoretical investigations. Among the first-fruits was the experimental verification of the predicted 4 R value for the series constant in the spectra of ionised magnesium, calcium and strontium.[5] Next, Sommerfeld's well-known extension of the theory of the hydrogen spectrum by taking account of the relativistic variation of the mass of the electron with its orbital velocity predicted a fine structure of the lines of hydrogen and of ionised helium which was almost immediately verified by Paschen's remarkable observations of the structure of ionised helium lines under very high resolving power.

A general explanation of the existence of several types of series S, P, D . . . in the spectra of more complex atoms immediately followed, namely, that such types of series are to be attributed to the action on the series electron of a perturbing field due to the presence of other electrons in the atom, producing a precessional motion similar to that associated with the relativity effect, but of very much greater value. Two quantum numbers thus became necessary in order to describe the motion of the series electron. They are usually written as n_k, where n is the 'principal' quantum number and k the so-called 'azimuthal' quantum number. In a simple ellipse, n determines the semi-major axis, and k the semi-minor axis; $kh/2\pi$ is the angular momentum of the electron. In the case of the simpler spectra first dealt with, the same quantum numbers could be used to specify the characters of the corresponding spectral terms, so that we have $k=1, 2, 3$ . . . corresponding to the term types S, P, D. . . .

[4] A. Fowler, *Mon. Not. R.A.S.*, vol. 73, p. 62 (1912).

[5] A. Fowler, *Phil. Trans.*, A, vol. 214, p. 225 (1914).

The verification of 9 R for doubly-ionised aluminium by Paschen (*Ann. d. Phys.*, vol. 71, p. 142, 1923), and of 16 R for trebly-ionised silicon by A. Fowler (*Roy. Soc. Proc.*, A, vol. 103, p. 413, 1923), followed in due course.

The azimuthal quantum number is the same for all terms of the same sequence, and, in accordance with the previous empirical deductions, considerations based upon Bohr's correspondence principle indicated theoretical reasons for the restriction imposed on combinations of terms of different types, namely, that terms of different types combine in ordinary circumstances only when their k values differ by unity.

When a series consists of doublets or triplets, 'inner' quantum numbers, usually represented by j, are introduced to distinguish the individual components; the accepted physical interpretation is that $jh/2\pi$ represents the resultant angular momentum of the entire atom, and fixes the orientation of the orbit of the series electron relative to the axis of the remainder of the atom (the atom core).

The theory also indicated an important relation between the ionisation potential of an element and the highest spectroscopic term, representing the normal state of the corresponding atom, which has been verified experimentally for numerous elements.[6] Indeed, the ionisation potentials of many elements can be determined with greater accuracy from series data than by direct measurements.

Other earlier successes of the quantum theory of spectra which should not be passed over without mention are Sommerfeld's derivation of a formula for the normal Zeeman effect in 1916, and the theoretical interpretation of the Stark effect, which was given independently by Schwarzschild and Epstein in the same year. The latter is rightly regarded as one of the greatest triumphs of the quantum theory, since classical electrodynamics had failed to give any explanation at all.

Following the pioneer work of Schwarzschild, Lenz and Heurlinger, the quantum theory has also been applied with conspicuous success to the highly complex band spectra of molecules by several workers, notably by Kratzer, Curtis, Jevons, and Mulliken. The underlying idea is that each component line of such a spectrum results from the simultaneous occurrence of three distinct quantum transitions, involving the electronic energy, the energy of nuclear vibration, and the energy of molecular rotation. In general, the quantum number of each may change by integral steps, and the complexity of the spectrum results from the great variety of possible changes. Of special interest is the application of the theory to the investigation of the isotopes of a given element.[7]

It will have been observed that while certain experimental data were essential for the formulation of the quantum theory of spectra, the theory has sometimes been in advance and has suggested new observations. I shall next refer to new discoveries in experimental work which have given a great impetus to theoretical investigations of a far-reaching character.

Apart from the first two groups and the aluminium sub-group of the periodic table, the spectra of the elements, with few exceptions, are extremely complex and long defied analysis. It is true that certain 'constant differences' had been noted in many of these spectra by Kayser and Runge, Paulson, and others, but these gave little knowledge of the real structure of the spectra. It was not until 1922 that a key to the

[6] See Foote and Mohler's *Origin of Spectra*, chap. 3 (1922).

[7] Mulliken, *Phys. Rev.*, vol. 25, p. 119 (1925), and other papers.

structure of complex spectra was furnished by the investigations of Catalán, who was then working at the Imperial College. Catalán first made an extended study of the spectrum of manganese,[8] in which series of triplets of somewhat peculiar character had already been partially disentangled by Kayser and Runge, and discovered that, while the principal and sharp series consisted of simple triplets, the members of the diffuse series each consisted of nine lines in place of the six which had up to that time been considered to characterise a diffuse ' triplet.' It followed that the D terms had five values, as against three values in calcium and other elements of the second group. Besides lines forming regular series, Catalán also identified several complex groups which he called ' multiplets,' one of which included as many as fourteen lines. In each multiplet the lines were of similar character and generally of the same class in King's temperature classification, and the lines could be arranged on a simple plan to show the regularity of their distribution.

The essential feature of Catalán's work was the discovery that in the arc and spark spectra of manganese, and in the arc spectrum of chromium, there were terms of greater complexity than the triple terms which had previously been recognised. It was this discovery that opened a way to the analysis of complex spectra in general. It has been pursued with amazing success by Catalán himself, Walters, Laporte, Meggers, Sommer, and others, and the main features of the structure of many spectra as complicated as that of iron have been revealed.

It is not necessary to go into all the intricate details of the spectra, because the general results can now be very simply summarised in consequence of the theoretical developments which have gone hand in hand with the experimental investigations. Bohr and Sommerfeld had already established certain ' selection rules ' for the combination of the terms of the simpler spectra on a quantum number basis, and, immediately following the work of Catalán, Sommerfeld showed that the scheme of ' inner quantum numbers ' which he had devised for the simpler spectra could be extended so as to fit the observations empirically. As other spectra came to be disentangled, an assignment of quantum numbers which appears to be adapted to all spectra was completed by Landé.[9]

In accordance with the work of Bohr, Sommerfeld and Landé, a spectral term may be represented by four quantum numbers, written in the form n^r_{kj} or ${}^r n_{kj}$. Here n is the *principal* quantum number, increasing by unity for successive terms of the same sequence[10]; k is the azimuthal quantum number and has the values 1, 2, 3, 4, 5 . . . . . . for the term types S, P, D, F, G, ... ; j is the *inner* quantum number, having one

[8] *Phil. Trans.*, A, vol. 223, p. 127 (1922).

[9] *Zeit. f. Phys.*, vol. 15, p. 189 (1923).

[10] For descriptive purposes the initial values assigned to n in the respective sequences of terms are of no great importance. In the Ritz-Paschen system of numeration, the first terms are 1S, 2P, 3D, 4F ; in the Rydberg system adopted in Fowler's ' Report on Series ' they are 1S, 1P, 2D (occasionally 1D), 3F. The latter system has the advantage that the term numbers are usually the integral parts of the ' effective quantum numbers,' *i.e.* the values of n^* in the expression $R/(n^*)^2$ for the terms. Paschen's numeration, however, has been extensively used. In theoretical investigations the values assigned to n are definitely associated with the corresponding values in the hydrogen spectrum.

or more values according as the term is single or multiple ; r represents the *maximum multiplicity* of terms in the system to which the term belongs, so that $r=1$ for singlets, 2 for doublets, 3 for triplets, and so on. Corresponding members of successive terms of the same sequence have the same values of j. Values of r, k, j different from those mentioned are used in certain theoretical discussions, but the above suffice for expressing the empirical results obtained in the analysis of spectra.

In practice the azimuthal quantum number is most conveniently indicated by retaining the old designations S, P, D, F . . . . . . for the term sequences, and the value of r representing the multiplicity of the system is now, by general agreement,[11] written on the upper left of the term symbol ; for example, $^3P_1$ represents a term of the triplet system for which $k=2$ and $j=1$. The values of j corresponding to the various terms and systems are collected in Table I.

TABLE I.

INNER QUANTUM NUMBERS.

Odd Multiplicities.

Terms	k	Singlet $r=1$	Triplet $r=3$	Quintet $r=5$	Septet $r=7$
S	1	0	1	2	3
P	2	1	0 1 2	1 2 3	2 3 4
D	3	2	1 2 3	0 1 2 3 4	1 2 3 4 5
F	4	3	2 3 4	1 2 3 4 5	0 1 2 3 4 5 6
G	5	4	3 4 5	2 3 4 5 6	1 2 3 4 5 6 7

Even Multiplicities.

Terms	k	Doublet $r=2$	Quartet $r=4$	Sextet $r=6$	Octet $r=8$
S	1	1	2	3	4
P	2	1 2	1 2 3	2 3 4	3 4 5
D	3	2 3	1 2 3 4	1 2 3 4 5	2 3 4 5 6
F	4	3 4	2 3 4 5	1 2 3 4 5 6	1 2 3 4 5 6 7
G	5	4 5	3 4 5 6	2 3 4 5 6 7	1 2 3 4 5 6 7 8

There is theoretically no limit to the number of types of terms, and other types H. . . . . . . are found for which $k>5$. In each system, however, the number of components in these additional types of terms never exceeds the maximum indicated by the value of r for the system.

It is to be noted that since *differences* of j values are alone embodied in the combination rules for inner quantum numbers, there is a certain arbitrariness in the values tabulated. With $j=0$ for the singlet S term and $j=1$ for the doublet S term, however, all the other values follow from the combinations indicated by observational data.

The selection rules regulating the term combinations of most general occurrence are :

For different types of terms : $\Delta k=\pm 1$.

[11] *Astrophys. Journ.*, vol. 61, p. 66 (1925).

For individual component terms: $\Delta j = \pm 1$ or 0, with $j=0$ to $j=0$ forbidden.

For systems of terms: $\Delta r = \pm 2$ or 0.

Thus, according to the first rule, D terms may be combined with P or F terms, but not with terms of types S or G. The second rule greatly reduces the number of combinations which are arithmetically possible, so that an FG combination in the octet system, for example, does not consist of 56 lines, but of 20; no individual term combines with more than three other terms of the same set. Although more than one system of terms may occur in the same spectrum, such systems are either all of odd or all of even multiplicity,[12] and the third rule indicates that, in addition to the ordinary combinations within the same system ($\Delta r=0$), there may be inter-system combinations for which $\Delta r=2$. Thus, terms of a singlet system may be found in combination with terms of a triplet system—still subject to the azimuthal and inner quantum number restrictions—but not with terms of a quintet system which might occur in the same spectrum.

In the more familiar spectra the components of multiple terms which have the smallest j values have the highest actual values, corresponding to deeper levels in the atom—i.e. ${}^{r}n_{kj} < {}^{r}n_{k,\,j\text{-}1}$. The more recent analyses of spectra, however, have revealed the frequent occurrence of 'inverted' terms, for which the components with largest j values have the largest actual values—i.e. ${}^{r}n_{kj} > {}^{r}n_{k,\,j\text{-}1}$. Such inverted terms are especially numerous in the spectra of the elements of the later groups of the periodic table, all the known terms of the iron arc spectrum (Fe I), for example, being inverted. 'Partially inverted' terms are also of occasional occurrence.

The general character of the regularities which appear in a group of lines resulting from the combination of two multiple terms will be best gathered from examples, which will at the same time illustrate applications of the inner quantum rules. The examples chosen are PD and DF quartet combinations from a recent analysis of the spectrum of ionised oxygen[13] (Table II).

The table is almost self-explanatory, but it should be mentioned that the suffixes are inner quantum numbers, and that the numbers in brackets which follow the wave-numbers representing the actual lines of the spectrum denote the relative intensities on a scale of ten for the maximum. The numbers printed in italics are differences of terms, or intervals separating lines in the multiplets; the slight departures from equality of corresponding intervals are due to difficulties of observation. It should further be noted that, while the relative values of the terms have been determined with considerable accuracy, the actual values quoted above are only approximate.

Apparent exceptions to the first selection rule, $\Delta k = \pm 1$, are of very frequent occurrence. In the spectra of the alkaline earths there are several groups of lines—some of them of great intensity—which do not belong to the regular series, but are related to them through the characteristic separations of the respective triplet systems, as was first recognised

[12] Neutral helium is possibly an exception.
[13] A. Fowler, *Roy. Soc. Proc.*, A, vol. 110, p. 497 (1926).

by Rydberg more than thirty years ago. Groups of this type were further investigated by Popow and by Götze,[14] and their real structure was deduced from observations of Zeeman effects. It then appeared that such a group was derived from combinations of P terms of the regular series with another set of P terms, or of ordinary D terms with a second set of D terms. The additional types of terms, which are usually distinguished as 'anomalous terms' and designated by P′, D′ . . . , have the same inner quantum numbers and show the same Zeeman effects as ordinary terms of corresponding types; but in their combinations with the regular terms they mostly follow the rule $\Delta k=0$, giving the combinations PP′, DD′. . . . Among themselves, however, the anomalous terms combine in accordance with the ordinary selection rule, $\Delta k=\pm 1$, giving such combinations as P′D′, D′F′. . . . Such terms are not restricted to the spectra of the alkaline earths, but have been found to be of very general occurrence in all but the simplest spectra.

Russell and Saunders[15] have since found other terms in the alkaline earth spectra which have the same combining properties as ordinary terms of corresponding types, but are anomalous in the sense that they do not form part of the regular term sequences; they have distinguished such terms by the convenient symbols, P″, D″. . . .

Further examples from the spectrum of ionised oxygen will conveniently indicate the selection rules applicable to quartet D′P′ and D′D combinations (Table III).

Multiplets formed from terms of higher multiplicities than those shown in the foregoing examples are built up on the same general plan, but naturally include a greater number of lines. The combination rules for anomalous terms have thus been more or less systematised, but exceptions to the selection rule for azimuthal quantum numbers occasionally occur also among regular terms. Thus in the arc spectrum of sodium there is a series of faint lines represented by $2^2P—m^2P$ (Lenard's series) and another by 2^2P-m^2F, corresponding to $\Delta k=0$ and $\Delta k=2$ respectively. Such combination lines are generally faint, except when produced under the influence of a strong electric field, in which case they may be very numerous. It should be observed, however, that the series $1^2S—m^2D$, for which $\Delta k=2$, appears in the absorption spectrum of potassium under conditions in which no electric field would appear to be present.[16] Exceptions to the inner quantum combination rule are very rare under ordinary conditions of observation, but such lines are especially liable to be excited in strong magnetic fields. Paschen and Back, for example, were able to excite the complete $^3P-^3D$ 'triplets' of Ca, Zn and Cd, the usual six lines in each being increased to nine. Among other observations which could be mentioned, extensive experiments on 'forbidden lines' in zinc, cadmium and mercury have been made by a number of Japanese physicists.[17]

[14] *Ann. d. Phys.*, vol. 66, p. 285 (1921).
[15] *Astrophys. Jour.*, vol. 61, p. 38 (1925).
[16] Datta, *Roy. Soc. Proc.*, A, vol. 99, p. 69 (1921); Foote, Mohler and Meggers, *Phil. Mag.*, vol. 43, p. 659 (1922).
[17] *E.g.*, Fukuda, Kuyama and Uchida, *Sc. Pap. No.* 56, *Inst. of Phys. and Chem. Res.* (1926).

Table II.

${}^4d\,{}^4p$ and ${}^4d\,{}^4f$ Combinations of O II.

Term Values.	d_4 78496·68		d_3 78621·30		d_2 78712·86		d_1 78768·40
		124·62		*91·56*		*55·54*	
ap_1 = 100263·84					21550·98(6)	*55·55*	21495·43(6)
105·32					*105·34*		*105·31*
ap_2 = 100158·52			21537·23(9)	*91·59*	21445·64(9)	*55·52*	21390·12(4)
158·52			*158·53*		*158·49*		
ap_3 = 100000·00	21503·32(10)	*124·62*	21378·70(8)	*91·55*	21287·15(2)		$(ap - d)$
bp_1 = 46872·88					31840·27(4r)	*55·37*	31895·64(3r)
105·22					*105·10*		*105·18*
bp_2 = 46767·66			31853·78(8r)	*91·59*	31945·37(7r)	*55·45*	32000·82(2r)
161·42			*161·36*		*161·38*		
bp_3 = 46606·24	31890·56(10r)	*124·58*	32015·14(6r)	*91·61*	32106·75(1r)		$(d - bp)$
f_2 = 54203·15			24418·05(0)	*91·69*	24509·74(4)	*55·57*	24565·31(4)
54·03			*54·15*		*53·96*		
f_3 = 54149·12	24347·57(0)	*124·63*	24472·20(3)	*91·50*	24563·70(6)		
77·91	*77·88*		*77·91*				
f_4 = 54071·21	24425·45(5)	*124·66*	24550·11(8)				
102·27	*102·29*						
f_5 = 53968·94	24527·74(10)						$(d - f)$

Table III.

${}^4d'\,{}^4p'$ and ${}^4d'\,{}^4d$ Combinations of O II.

Term Values.	d'_4 52745·34		d'_3 52751·69		d'_2 52753·22		d'_1 52753·69
		6·35		*1·53*		*0·47*	
p'_1 = 77153·03					24399·76(4)	*0·42*	24399·34 (1)
46·10					*46·08*		
p'_2 = 77106·93			24355·24(5)	*1·56*	24353·68(7)		[24353·26]
91·97			*91·99*		*91·90*		
p'_3 = 77014·96	24269·61(8)	*6·36*	24263·25(3)	*1·47*	24261·78(2)		$(p' - d')$
d_1 = 78768·40					26015·20(3)		[26014·71]
55·54					*55·51*		
d_2 = 78712·86			25961·22(2)	*1·53*	25959·69(3)		[25959·17]
91·56			*91·63*		*91·63*		
d_3 = 78621·30	25875·96(2)	*6·37*	25869·59(5)	*1·53*	25868·06(1)		
124·62	*124·59*		*124·57*				
d_4 = 78496·68	25751·37(7)	*6·35*	25745·02(3)				$(d - d')$

In the actual analysis of a spectrum, the selection rules which have been indicated for the combination of terms are supplemented in a very practical way by Sommerfeld's 'intensity rule' and to a less degree by Landé's 'interval rule.'

The intensity rule was indicated in the first instance in connection with the simpler spectra, but has since been found to be of general application. It is to the effect that lines for which the changes in j and k are in the same direction are the strongest, while those for which the changes are of opposite sign are the weakest. Thus, in the $^4D^4P$ combination previously shown, where k is 3 for D and 2 for P, the strongest line is D_4P_3, while the weakest is D_2P_3; the same rule holds good for the combination $^4D'^4P'$. In combinations of ordinary and anomalous (or 'primed') terms, however, such as $^4D^4D'$ previously tabulated, k is the same for both, and the strongest line is that resulting from the terms having the largest (identical) j values (D'_4D_4). The detailed relations may easily be gathered from the examples of multiplet structures given above.

The whole question of intensities in related groups of lines has recently been placed on a quantitative basis through photometric measurements initiated by Ornstein, Burger and Dorgelo at Utrecht. It results that the intensities in such groups are in the ratio of integers, and it may accordingly be concluded that intensities, like frequencies, are determined by quantum considerations. In an application of the correspondence principle Sommerfeld and Heisenberg had already investigated the probabilities of emission, and formulæ for computing the relative intensities in multiplets on this basis have since been deduced.[18] Russell has found excellent agreement between calculated and observed values in an extensive comparison with the approximate experimental data available. Further photometric measurements to test the formulæ are much to be desired. The constancy or otherwise of the intensity relations in the same multiplet under different conditions of excitation is a question which also calls for the attention of experimental workers.

In general the separations between successive components of a multiple term increase as the inner quantum number j increases. In systems of odd multiplicity these separations are approximately proportional to the larger values of j; thus in a triplet P term with $j=2, 1, 0$, the separations are in the ratio 2 : 1. In a group of terms of even multiplicity the separations are proportional to the means of the j values; in a quartet P term, for example, $j=3, 2, 1$, and the separations are in the ratio 5 : 3; for a sextet system the rule gives the ratio 7 : 5 for the P separations. The interval rule in its present form, however, frequently breaks down, as is emphasised especially by Hicks.[19]

The characteristics of the various systems and types of terms which are outlined above are sufficient for the classification of the lines of most spectra in a form adapted for theoretical investigations. The quantum numbers which have been assigned, however, may be considered entirely

[18] Ornstein and Burger, *Zeit. f. Phys.*, vol. 31, p. 355 (1925). Kronig, *Zeit. f. Phys.*, vol. 31, p. 885; vol. 32, p. 261 (1925). Sommerfeld and Hönl, *Sitz. Preuss. Akad. Wiss.*, vol. 9, p. 141 (1925). Russell, *Proc. Nat. Acad. Wash.*, vol. 11, p. 314 (1925).

[19] *Phil. Mag.*, vol. 48, p. 1036 (1924).

empirical so far as they are concerned in the mere analysis of a spectrum, and are subject to such modifications as may be indicated by theoretical considerations.

Unfortunately, the analysis of a spectrum does not always lead to a knowledge of the actual values of the terms, or energy levels. These can be determined for any of the relatively simple spectra, in which comparatively extended series can be traced and their limits calculated. In most of the complex spectra, only the relative values of the terms have been deduced, since extended sequences in these spectra are apparently of rare occurrence. Even for these, however, the term of highest numerical value, representing the lowest energy level, can often be identified, and this is of special value in view of its association with the normal state of the atom.

This completes the story of spectroscopic terms and their possible combinations on what might be called a purely numerical basis; that is, in so far as the analysis of a spectrum can at present be based merely on a table of wave-lengths and intensities. Especially as regards the more complex spectra, however, advantage has to be taken of every possible experimental aid to the classification of the lines—particularly, in the first instance, as a means of sorting out the lines characteristic of an element at different stages of ionisation. I shall return to this subject later.

Thanks to the industry of numerous workers, many of the complex spectra have now been partially analysed, and two of the principal generalisations foreshadowed some years ago have been greatly strengthened. The first of these is expressed by the so-called 'alternation law,' according to which the arc spectra of the elements are alternately of even and odd multiplicities in passing from the first to the higher groups of the periodic table. No exceptions to the rule have yet been found. Until recently it was thought that the maximum term multiplicity was equal to the chemical group number increased by unity, but recent work has shown that this simple rule is not of general application; for example, in the arc spectrum of copper quartets occur as well as doublets.[20]

The second generalisation is expressed by the spectroscopic 'displacement law,' which states that the first spark (enhanced) spectrum of an element has a structure similar to that of the arc spectrum of the element which precedes it in the periodic table. To make this generally applicable, however, it is necessary to qualify the rule by restricting the meaning of similarity to a common odd or even multiplicity. The spectrum of ionised scandium, for example, though including singlet and triplet terms, differs from the spectrum of neutral calcium in having a ^3D term in place of a ^1S term corresponding to the normal state. The same rule may be extended to higher states of ionisation, the second spark spectrum, for example, resembling the first spark spectrum of the preceding element, or the arc spectrum of the element of atomic number two units smaller. Clearly the alternation law of multiplicities is also applicable when the first or higher orders of spark spectra of the elements are respectively compared.

[20] Shenstone, *Phil. Mag.*, vol. 49 (May 1925); Beals, *Roy. Soc. Proc.*, A, vol. 111, p. 168 (1926).

The above rules have by no means been proved for all elements, but they are true for all spectra which have been disentangled up to the present time, and may safely be adopted as a starting-point in the analysis of further spectra. They have been almost completely verified for the elements of the two short periods Li (3) to Cl (17), but may be more effectively illustrated by the arc spectra of the elements K (19) to Ni (28) by the use of data collected by Catalán,[21] which are given in Table IV.

The table includes references to the 'ground term' (*i.e.* the highest term or deepest energy level), and indicates also the regular or inverted character of the terms.

TABLE IV.

TERM SYSTEMS IN ARC SPECTRA, K–NI.

Group.	I	II	III	IV	V	VI	VII	VIII		
Element.	19.K	20.Ca	21.Sc	22.Ti	23.V	24.Cr	25.Mn	26.Fe	27.Co	28.Ni
Multi-plicities	2	1 3	2 4	1 3 5	2 4 6	3 5 7	4 6 8	3 5 7	2 4 6	1 3 5
Ground term	^2S	^1S	^2D	^3F	^4F	^7S	^6S	^5D	^4F	^3F
Class of terms	Reg.	Reg.	Reg.	Reg.	Reg.	Reg.	Reg. & Inv.	Inv.	Inv.	Inv.

For the elements Rb–Pd, similar data collected by Meggers and Kiess[22] are given in Table V.

TABLE V.

TERM SYSTEMS IN ARC SPECTRA, RB–PD.

Group	I	II	III	IV	V	VI	VII	VIII		
Element.	37.Rb	38.Sr	39.Y	40.Zr	41.Nb	42.Mo	43.Ma	44.Ru	45.Rh	46.Pd
Multi-plicities	2	1 3	2 4	1? 3 5	2? 4 6	3 5 7	(4) (6) (8)	3 5 (7)	2 4 (6)	1 3 (5)
Ground term	^2S	^1S	^2D	^5F	^6D	^7S	(^6D)	^5F	^4F	^1S

NOTE.—The numbers in brackets have been filled in from considerations of symmetry.

[21] *An. Soc. Esp. Fis. y Quimica*, vol. 23, p. 403 (1925).
[22] *Jour. Opt. Soc. Amer.*, vol. 12, p. 446 (1926).

Catalán has remarked that, in passing from Ca to Ni, the terms are regular so long as the maximum multiplicity is increasing, and inverted when it is decreasing, both classes of terms occurring at the turning-point (Mn), as shown in Table IV. A similar alternation of even and odd multiplicities is shown by the spark spectra of the elements Ca to Ni, as will appear from Table VI, which is also taken from Meggers and Kiess. The data here are less complete and for Co^+ and Ni^+ they are merely conjectural.

TABLE VI.

TERM SYSTEMS IN SPARK SPECTRA, Ca^+–Ni^+.

Group	I	II	III	IV	V	VI	VII	VIII		
Element	19.K^+	20.Ca^+	21.Sc^+	22.Ti^+	23.V^+	24.Cr^+	25.Mn^+	26.Fe^+	27.Co^+	28.Ni^+
Multi-plicities			1		1?				(1)	
		2		2		2?		2?		(2)
			3		3		3?		(3)	
				4		4		4		(4)
					5		5		(5)	
						6		6		
							7			
Ground term		^2S	^3D	^4F	^5F	^6S	^7S	^6D	(^5F)	(^4F)

The spark spectra of only very few of the elements of the next row (Rb–Pd) have at present been classified, but these are in accordance with the above so far as they go. Thus 38.Sr^+=doublets; 39.Y^+=singlets and triplets; 40.Zr^+=doublets and quartets.

It will be observed that the alternation law and restricted displacement law are completely satisfied by the observational data included in the tables, and the same appears to be true for other spectra which have been sufficiently analysed. The tables, however, bring out several other points of interest. It will be noted, for example, that not more than three different systems of terms have yet been found in the same spectrum, and it would seem probable that this is the actual maximum number which can occur.

A very striking relation, to which attention appears to have first been directed by Hund,[23] is that, as regards the ground term, the spark spectrum of each of the elements Ca to Ni is more closely related to its own arc spectrum than to the arc spectrum of the preceding element. Thus, from Ca to Fe, the ground terms of the arc and spark spectra are of the same type, and, apart from Cr, which is in certain other respects exceptional, the multiplicity of the system to which the ground term belongs is increased by unity in passing from the arc to the spark spectrum. This may be shown as follows :—

	20.Ca	21.Sc	22.Ti	23.V	24.Cr	25.Mn	26.Fe	27.Co	28.Ni
Arc . .	^1S	^2D	^3F	^4F	^7S	^6S	^5D	^4F	^3F
Spark . .	^2S	^3D	^4F	^5F	^6S	^7S	^6D	(^5F)	(^4F)

[23] *Zeit. f. Phys.*, vol. 33, p. 362 (1925).

It is not improbable that such systematic relations will be of considerable assistance in the unravelling of the numerous complicated spectra which remain to be investigated.

The more recent results of the analysis of complex spectra have provided an ordered knowledge of a multitude of facts which have an important bearing upon the development of the theory of spectra and the arrangement of electrons in the outer parts of normal atoms. Theoretical workers have not been slow to utilise the new data, and have, indeed, frequently been able to forge ahead of experimental results. I shall not attempt to discuss in detail these theoretical developments, more especially as a critical discussion by Prof. J. H. Van Vleck has been published very recently.[24] It will suffice to refer briefly to the more important steps in the interpretation of the empirically known spectra, as supplementing the interpretation of the simpler spectra previously given by Bohr.

Among the principal problems immediately resulting from the analysis of the more complex spectra are those indicated by the existence of anomalous terms, the absence of extended sequences of terms in most of the complex spectra, and the question of reconciling our ideas of the arrangement of electrons in the outer parts of atoms with the structure of the spectra—in particular with the occurrence as ground terms of such types as ^5F.

These problems, however, are not independent of one another. It will be recalled that the existence of sequences of terms involving the Rydberg constant, in the spectra of elements whose atoms contain more than one electron, was explained by Bohr on the assumption that the spectra were generated by the transitions of a single electron between orbits in an approximately Coulomb field arising from the unchanged remainder of the atom. This, however, is not a process which, in the absence of experimental evidence, would be expected to take place in all atoms. Excitation of a complex atom might well be expected to involve simultaneous disturbances of more than one electron, and the fact that many spectra do not appear to exhibit Rydberg sequences naturally leads to a consideration of the possibility that such simultaneous disturbances actually take place. Again, the occurrence of unexpected ground terms is a matter for surprise only when the ground term of a spectrum is directly associated with the innermost orbit of the series electron. If there is no uniquely characterised 'series electron,' there is no reason to expect any particular type of term to be the highest, and the problem of determining the ground term is merged into that of deducing the spectroscopic terms (anomalous as well as regular) from the simultaneous movements of the disturbed electrons. The problems of complex spectra thus resolve themselves into two—first, the distribution of the electrons among the various possible types of orbit; and, second, the deduction of spectroscopic terms from a given distribution of electrons.

In the consideration of the first problem we are not confined to the evidence afforded by optical spectra. Other data towards this end are

[24] 'Quantum Principles and Line Spectra.' *Bulletin No.* 54. *Nat. Res. Council, Washington* (1926).

Table VII.

X-Ray Levels and Optical Terms.

$k=1$	$j=1$	K 1_{11} $1s_1$	L_I 2_{11} $2s_1$	M_I 3_{11} $3s_1$	N_I 4_{11} $4s_1$	O_I 5_{11} $5s_1$
$k=2$	$j=1$		L_{II} 2_{21} $2p_1$	M_{II} 3_{21} $3p_1$	N_{II} 4_{21} $4p_1$	O_{II} 5_{21} $5p_1$
	$j=2$		L_{III} 2_{22} $2p_2$	M_{III} 3_{22} $3p_2$	N_{III} 4_{22} $4p_2$	O_{III} 5_{22} $5p_2$
$k=3$	$j=2$			M_{IV} 3_{32} $3d_2$	N_{IV} 4_{32} $4d_2$	O_{IV} 5_{32} $5d_2$
	$j=3$			M_V 3_{33} $3d_3$	N_V 4_{33} $4d_3$	O_V 5_{33} $5d_3$
$k=4$	$j=3$				N_{VI} 4_{43} $4f_3$	$5f_3$
	$j=4$				N_{VII} 4_{44} $4f_4$	$5f_4$

Table VIII.

Arrangement of Electrons in Rare Gases.

Bohr.

	Atomic Number	K 1_1	L 2_1	2_2	M 3_1	3_2	3_3	N 4_1	4_2	4_3	4_4
He	2	2									
Ne	10	2	4	4							
A	18	2	4	4	4	4					
Kr	36	2	4	4	6	6	6	4	4		

Main Smith and Stoner.

	Atomic Number	K 1_{11}	L 2_{11}	2_{21}	2_{22}	M 3_{11}	3_{21}	3_{22}	3_{32}	3_{33}	N 4_{11}	4_{21}	4_{22}......
He	2	2											
Ne	10	2	2	2	4								
A	18	2	2	2	4	2	2	4					
Kr	36	2	2	2	4	2	2	4	4	6	2	2	4
	$n_k=$	1_1	2_1	2_2		3_1	3_2		3_3		4_1	4_2	

furnished by X-ray spectra and by the variations of the chemical and physical properties of the elements according to their positions in the periodic classification. Bohr's well-known table of electron orbits (1922) was built up by taking account of these properties and considering the formation of atoms by the successive capture and binding of electrons. The orbits themselves were distinguished by the quantum numbers n_k ($k \leq n$), and it was assumed that the orbits of the earlier bound electrons were essentially unchanged when another electron was introduced into the system. The classification was notably successful in accounting for the appearance, at certain stages, of elements which deviate in their properties from corresponding elements of the previous periods.

These ideas of Bohr have been remarkably developed in recent years, especially through the work of Main Smith[25] and Stoner,[26] who independently arrived at similar conclusions, chiefly from the consideration of chemical and physical properties respectively. Whereas Bohr had considered only the distribution of electrons among sub-levels defined by the quantum numbers n_k, Main Smith and Stoner suggested a distribution among all the sub-levels which were known to exist from X-ray spectra, and which were characterised by the three quantum numbers n_{kj}. In partial justification of the proposed new distribution of electrons in the different groups, Stoner pointed to the remarkable analogy between the accepted classification of X-ray levels and the terms of the optical doublet spectra of the alkali metals which had previously been discussed by Landé. This correspondence between X-ray and alkali terms may perhaps be most conveniently shown in the form adopted by Wentzel, as in Table VII.

The combinations between the X-ray terms are governed by precisely the same selection rules as those between the optical terms, and it can scarcely be doubted that the two types of doublets have a similar origin. This analogy was regarded by Stoner as strong justification for assuming a relation between the inner quantum number and the number of electrons in a sub-group. His reasoning was as follows. In the case of alkali doublets, if the inner quantum numbers are given the values shown above (k and $k-1$), the number of components into which each term is split in a weak magnetic field, as revealed by observation, is double the inner quantum number (*e.g.* 2 for S, 2 for P_1, and 4 for P_2). Since, therefore, there are $2j$ possible states of the atom corresponding to each energy level n_{kj} (distinguishable, however, only when there is an external magnetic field), it seems reasonable to suppose that the number of 'possible and equally probable' orbits n_{kj} also is $2j$; *i.e.* that there are $2j$ electrons in a complete sub-group n_{kj}. Although the doublet term values seem to depend primarily on the *outermost* electron orbits, Stoner suggested that the rule might be of general application. The distinction between orbits having the same values of n_{kj} was ascribed to differences in orientation with respect to the atom as a whole.

These considerations led Stoner independently to an electron distribution similar to that proposed by Main Smith and differing in important

[25] *Chemistry and Atomic Structure*, London, 1924; *Review of Chemistry and Industry*, March 28, 1924.

[26] *Phil. Mag.*, vol. 47, p. 719 (1924); vol. 49, p. 1289 (1925).

details from that first given by Bohr. In the new scheme the inner sub-levels are completed at an earlier stage, and there is a greater concentration of electrons in the outer sub-levels of each group. For the present the nature of the modification will be sufficiently indicated by comparing the electron distribution among the sub-levels in helium, neon, argon and krypton, according to the old and new arrangements.

With the j values assigned above, the total number of electrons required to fill each n_k group is double the sum of the inner quantum numbers for the group. From the relation of the j's and k's, however, the number may also be considered as being equal to $2(2k-1)$.

In this connection it should be observed that Sommerfeld and others now assign half-integral values to j in term systems of even multiplicity, so that, although integral values as above are most frequently adopted for convenience of writing and printing, it is to be understood that they are to be reduced by $\frac{1}{2}$ for certain purposes. With this modification the number of electrons in each sub-level is equal to $2j+1$, which Sommerfeld calls the 'quantum weight,' representing the number of possible orientations of the angular momentum, j, in a magnetic field.

The new scheme of electron distribution was shown by Stoner to be supported by a consideration of the intensities of X-ray lines, the absorption of X-rays, chemical and magnetic properties, and optical spectra. It retains all the essential features of Bohr's picture of the building up of atoms, and is equally in accord with chemical considerations, as is especially shown by the work of Main Smith.

The electronic arrangements of all the elements from 1 to 92, in their normal states, may now be specified with considerable confidence. They are indicated in Table IX, which, with slight modifications, has been taken from a paper by Foote.[27] The spectroscopic ground term associated with the normal state of each neutral atom is shown in the fourth column, the values directly determined from spectra being marked with an asterisk, while the remainder are the ground terms predicted by the new theory of complex spectra.

[27] *Amer. Inst. Mining and Metallurgy*, Sc. Paper No. 1547D (1926).

Table IX.

Arrangement of Electrons in Atoms.

Period	Atomic Number	Element	Spectroscopic Term, ^{r}l	Number of Electrons in Shell of Quantum Number $n_{kk'}$											
				K 1_{11}	L_I 2_{11}	L_{II} 2_{21}	L_{III} 2_{22}	M_I 3_{11}	M_{II} 3_{21}	M_{III} 3_{22}	M_{IV} 3_{32}	M_V 3_{33}	N_I 4_{11}	N_{II} 4_{21}	N_{III} 4_{22}
1	1	H		1											
	2	He	$^1S_0$ *	2											
2	3	Li	$^2S_{\frac{1}{2}}$ *	2	1										
	4	Be	$^1S_0$	2	2										
	5	B	$^2P_{\frac{1}{2}}$	2	2	1									
	6	C	$^3P_0$	2	2	2									
	7	N	$^4S_{\frac{3}{2}}$	2	2	2	1								
	8	O	$^3P_2$ *	2	2	2	2								
	9	F	$^2P_{\frac{3}{2}}$	2	2	2	3								
	10	Ne	$^1S_0$ *	2	2	2	4								
3	11	Na	$^2S_{\frac{1}{2}}$ *	2	2	2	4	1							
	12	Mg	$^1S_0$ *	2	2	2	4	2							
	13	Al	$^2P_{\frac{1}{2}}$ *	2	2	2	4	2	1						
	14	Si	$^3P_0$ *	2	2	2	4	2	2						
	15	P	$^4S_{\frac{3}{2}}$	2	2	2	4	2	2	1					
	16	S	$^3P_2$ *	2	2	2	4	2	2	2					
	17	Cl	$^2P_{\frac{3}{2}}$	2	2	2	4	2	2	3					
	18	A	$^1S_0$	2	2	2	4	2	2	4					
4	19	K	$^2S_{\frac{1}{2}}$ *	2	2	2	4	2	2	4			1		
	20	Ca	$^1S_0$ *	2	2	2	4	2	2	4			2		
	21	Sc	$^2D_{\frac{3}{2}}$ *	2	2	2	4	2	2	4	1		2		
	22	Ti	$^3F_2$ *	2	2	2	4	2	2	4	2		2		
	23	V	$^4F_{\frac{3}{2}}$ *	2	2	2	4	2	2	4	3		2		
	24	Cr	$^7S_3$ *	2	2	2	4	2	2	4	4	1	1		
	25	Mn	$^6S_{\frac{5}{2}}$ *	2	2	2	4	2	2	4	4	1	2		
	26	Fe	$^5D_4$ *	2	2	2	4	2	2	4	4	2	2		
	27	Co	$^4F_{\frac{9}{2}}$ *	2	2	2	4	2	2	4	4	3	2		
	28	Ni	$^3F_4$ *	2	2	2	4	2	2	4	4	4	2		
	29	Cu	$^2S_{\frac{1}{2}}$ *	2	2	2	4	2	2	4	4	6	1		
	30	Zn	$^1S_0$ *	2	2	2	4	2	2	4	4	6	2		
	31	Ga	$^2P_{\frac{1}{2}}$ *	2	2	2	4	2	2	4	4	6	2	1	
	32	Ge	$^3P_0$	2	2	2	4	2	2	4	4	6	2	2	
	33	As	$^4S_{\frac{3}{2}}$	2	2	2	4	2	2	4	4	6	2	2	1
	34	Se	$^3P_2$	2	2	2	4	2	2	4	4	6	2	2	2
	35	Br	$^2P_{\frac{3}{2}}$	2	2	2	4	2	2	4	4	6	2	2	3
	36	Kr	$^1S_0$	2	2	2	4	2	2	4	4	6	2	2	4

TABLE IX.

ARRANGEMENT OF ELECTRONS IN ATOMS—(*Continued*).

K, L, and M Shells like Kr Complete with 28 Electrons.

Period	Atomic Number	Element	Spectroscopic Term, rl_j	Number of Electrons in Shell of Quantum Number $n_{kk'}$											
				N_I 4_{11}	N_{II} 4_{21}	N_{III} 4_{22}	N_{IV} 4_{32}	N_V 4_{33}	N_{VI} 4_{43}	N_{VII} 4_{44}	O_I 5_{11}	O_{II} 5_{21}	O_{III} 5_{22}	O_{IV} 5_{32}	P_I 6_{11}
5	37	Rb	$^2S_{\frac{1}{2}}$ *	2	2	4					1				
	38	Sr	$^1S_0$ *	2	2	4					2				
	39	Y	$^2D_{\frac{3}{2}}$ *	2	2	4	1				2				
	40	Zr	$^3F_2$ *	2	2	4	2				2				
	41	Nb	$^6D_{\frac{1}{2}}$ *	2	2	4	4				1				
	42	Mo	$^7S_3$ *	2	2	4	4	1			1				
	43	Ma	$^6D_{\frac{9}{2}}$	2	2	4	4	(2)-			(1)				
	44	Ru	$^5F_5$ *	2	2	4	4	3			1				
	45	Rh	$^4F_{\frac{9}{2}}$ *	2	2	4	4	4			1				
	46	Pd	$^1S_0$ *	2	2	4	4	6							
	47	Ag	$^2S_{\frac{1}{2}}$ *	2	2	4	4	6			1				
	48	Cd	$^1S_0$ *	2	2	4	4	6			2				
	49	In	$^2P_{\frac{1}{2}}$ *	2	2	4	4	6			2	1			
	50	Sn	$^3P_0$ *	2	2	4	4	6			2	2			
	51	Sb	$^4S_{\frac{3}{2}}$	2	2	4	4	6			2	2	1		
	52	Te	$^3P_2$	2	2	4	4	6			2	2	2		
	53	I	$^2P_{\frac{3}{2}}$	2	2	4	4	6			2	2	3		
	54	Xe	$^1S_0$	2	2	4	4	6			2	2	4		
6	55	Cs	$^2S_{\frac{1}{2}}$ *	2	2	4	4	6			2	2	4		1
	56	Ba	$^1S_0$ *	2	2	4	4	6			2	2	4		2
	57	La	$^2D_{\frac{3}{2}}$	2	2	4	4	6			2	2	4	1	2
	58	Ce	$^3H_4$	2	2	4	4	6	1		2	2	4	1	2
	59	Pr	$^4K_{\frac{11}{2}}$	2	2	4	4	6	2		2	2	4	1	2
	60	Nd	$^5L_6$	2	2	4	4	6	3		2	2	4	1	2
	61		$^6L_{\frac{11}{2}}$	2	2	4	4	6	4		2	2	4	1	2
	62	Sm	$^7K_4$	2	2	4	4	6	5		2	2	4	1	2
	63	Eu	$^8H_{\frac{3}{2}}$	2	2	4	4	6	6		2	2	4	1	2
	64	Gd	$^9D_6$	2	2	4	4	6	6	1	2	2	4	1	2
	65	Tb	$^8H_{\frac{17}{2}}$	2	2	4	4	6	6	2	2	2	4	1	2
	66	Dy	$^7K_{10}$	2	2	4	4	6	6	3	2	2	4	1	2
	67	Ho	$^6L_{\frac{21}{2}}$	2	2	4	4	6	6	4	2	2	4	1	2
	68	Er	$^5L_{10}$	2	2	4	4	6	6	5	2	2	4	1	2
	69	Tm	$^4K_{\frac{17}{2}}$	2	2	4	4	6	6	6	2	2	4	1	2
	70	Yb	$^3H_6$	2	2	4	4	6	6	7	2	2	4	1	2
	71	Lu	$^2D_{\frac{5}{2}}$	2	2	4	4	6	6	8	2	2	4	1	2

Table IX.

Arrangement of Electrons in Atoms—(*Continued*).

K, L, M and N Shells like Lu Complete with 60 Electrons.

Period	Atomic Number	Element	Spectroscopic Term, $^{r}l_{j}$	Number of Electrons in Shell of Quantum Number $n_{kk'}$									
				O_{I} 5_{11}	O_{II} 5_{21}	O_{III} 5_{22}	O_{IV} 5_{32}	O_{V} 5_{33}	P_{I} 6_{11}	P_{II} 6_{21}	P_{III} 6_{22}	P_{IV} 6_{32}	Q_{I} 7_{11}
	72	Hf	$^{3}F_{2}$	2	2	4	2		2				
	73	Ta	$^{4}F_{\frac{3}{2}}$	2	2	4	3		2				
	74	W	$^{5}D_{0}$ *	2	2	4	4		2				
	75	Re	$^{6}S_{\frac{5}{2}}$	2	2	4	4	1	2				
			$^{6}D_{\frac{9}{2}}$					2	1				
	76	Os	$^{5}D_{4}$	2	2	4	4	2	2				
			$^{5}F_{5}$					3	1				
	77	Ir	$^{4}F_{\frac{9}{2}}$	2	2	4	4	3	2				
			$^{4}F_{\frac{9}{2}}$					4	1				
	78	Pt	$^{3}D_{3}$	2	2	4	4	5	1				
	79	Au	$^{2}S_{\frac{1}{2}}$ *	2	2	4	4	6	1				
	80	Hg	$^{1}S_{0}$ *	2	2	4	4	6	2				
	81	Tl	$^{2}P_{\frac{1}{2}}$ *	2	2	4	4	6	2	1			
	82	Pb	$^{3}P_{0}$ *	2	2	4	4	6	2	2			
	83	Bi	$^{4}S_{\frac{3}{2}}$	2	2	4	4	6	2	2	1		
	84	Po	$^{3}P_{2}$	2	2	4	4	6	2	2	2		
	85		$^{2}P_{\frac{3}{2}}$	2	2	4	4	6	2	2	3		
	86	Rn	$^{1}S_{0}$	2	2	4	4	6	2	2	4		
7	87		$^{2}S_{\frac{1}{2}}$	2	2	4	4	6	2	2	4		1
	88	Ra	$^{1}S_{0}$	2	2	4	4	6	2	2	4		2
	89	Ac	$^{2}D_{\frac{3}{2}}$	2	2	4	4	6	2	2	4	(1)	(2)
	90	Th	$^{3}F_{2}$	2	2	4	4	6	2	2	4	(2)	(2)
	91	PAc	$^{4}F_{\frac{3}{2}}$	2	2	4	4	6	2	2	4	(3)	(2)
	92	U	$^{5}D_{0}$	2	2	4	4	6	2	2	4	(4)	(2)

With the attainment of a definite conception of the electronic structure of the various atoms it becomes possible to approach the second of the two problems referred to above, namely, the determination of the spectroscopic terms associated with a given distribution of electron orbits. The first steps were taken by Russell and Saunders,[28] and independently in part by Wentzel,[29] who, in a discussion of the so-called 'anomalous' terms, which have already been mentioned, made one of the most illuminating contributions to spectroscopy of recent years. To the three $^3PP'$ groups of calcium already known two more were added by Russell and Saunders, who were thus able to show that the five groups formed a series which could be approximately represented by a Ritz formula. The surprising result then appeared that, as referred to the regular triplet limits, the later P′ terms were numerically negative. The earlier P′ terms, having positive values, certainly originated in the neutral atom, and it could scarcely be doubted that the later terms also had the same origin.

The existence of these negative terms implies a greater equivalent energy than that required for ionisation of the atom, and it follows that it is possible for an atom to remain neutral while absorbing more energy than that necessary to remove the series electron. Hence, in accordance with a previous suggestion made by Bohr, but unknown to them, Russell and Saunders concluded that the energy must be divided between two (or more) electrons, each of which is displaced to a higher energy level, without the removal of either of them. The detailed numerical evidence led inevitably to the conclusion that both valence electrons might jump at the same time from outer to inner orbits, and that the net loss of energy would then be radiated as a single quantum, *i.e.* as monochromatic emission. Epstein has shown that such simultaneous transitions of two electrons, with the emission of a single quantum of energy, is consistent with the correspondence principle, and similar combinations of transitions into a single emission had already been found to be involved in the theory of band spectra.

Experimental evidence in support of this view of the origin of the anomalous terms in neutral atoms of the alkaline earths is afforded by the fact that such terms do not appear in the spectra of the alkalis, where the energy required to displace a second electron is known to be much greater than that for the first. Additional evidence is provided by the observation that they do occur in the spectra of most of the elements in which enhanced lines are easily produced. It may be added, in further support of the hypothesis, that PP′ groups appear conspicuously in the arc spectrum of silicon, in which lines of the ionised atom are entirely wanting.

In their theoretical discussion Russell and Saunders showed that the anomalous relations could be explained by assuming that the angular momenta of the two valence electrons are quantised in space with respect to each other, and their resultant quantised with respect to the angular momentum of the residue of the atom.

Arising out of the work of Russell and Saunders, together with further

[28] *Phys. Rev.*, vol. 22, p. 201 (1923); *Astrophys. Jour.*, vol. 61, p. 38 (1925).
[29] *Phys. Zeit.*, vol. 24, p. 106 (1923); vol. 25, p. 182 (1924).

contributions by Pauli,[30] Goudsmit,[31] and Heisenberg,[32] a general theory of complex spectra has been developed in a practical form by Hund.[33] By a complex spectrum, from this point of view, is to be understood the spectrum of an atom which contains more than one electron with $k>1$ in outer uncompleted n_k groups. Thus, while aluminium, with two of the outermost electrons in 3_1 orbits and *one* in a 3_2 orbit, gives a 'simple' spectrum, the next element, silicon, with *two* electrons in 3_2 orbits, gives a 'complex' spectrum. The theory enables the deeper spectrum terms corresponding to any specified configuration of electrons to be determined with considerable certainty. While it adds nothing to the theory of simple spectra, the theory is clearly of great importance in relation to spectra of greater complexity. It shows, for example, that deep-lying terms which must be classed as F terms on account of combination properties and Zeeman effects, are quite compatible with low values of the angular momenta of the individual electrons.

It is a fundamental feature of the new theory that, in a complex spectrum, the quantum numbers which specify an electron orbit are quite distinct from those which specify a spectroscopic term. The former are five in number, viz., n, k_1, k_2, m_1, m_2. The latter, which number three, are represented by r, l, j. n is the principal quantum number as previously defined; k_1 is equal to $k-\frac{1}{2}$ (where k is the azimuthal quantum number); k_2 may be either $k_1-\frac{1}{2}$ or $k_1+\frac{1}{2}$; and m_1 and m_2, which are expressible in terms of k_1 and k_2, are the magnetic quantum numbers for weak and strong fields respectively. The term quantum numbers are defined as follows: r is half the multiplicity of the system; l denotes the type of term ($l=\frac{1}{2}, \frac{3}{2}, \frac{5}{2}$ . . . for S, P, D . . . terms respectively); and j is the inner quantum number which distinguishes the components of a given l term. The theory consists of semi-empirical rules for deducing r, l, and j for the deeper-lying terms from the quantum numbers of the electrons in uncompleted groups.

The assignment of five quantum numbers to each electron orbit is due to Pauli, who supplemented it by a hypothesis—generally known as Pauli's principle—which asserts that no two electrons in an atom can occupy orbits having the same values for these five quantities. This principle can be shown to lead immediately to the scheme of electron distribution suggested by Main Smith and Stoner; so that in deducing spectroscopic terms from the orbital quantum numbers given above, it is consistent, and even necessary, to deal with the particular orbits given by Main Smith and Stoner's scheme.

It is impossible here to give in detail the procedure to be followed in deriving the terms; when the rules are grasped it becomes mainly a matter of arithmetic. There is a particular case, however, in which the calculation is greatly simplified. If the normal state of an ionised atom is known to be specified by values, r=R, l=L, then the neutral atom, formed by the addition of an electron in an n_k orbit (provided n, k are not

[30] *Zeit. f. Phys.*, vol. 31, p. 765 (1925).
[31] *Zeit. f. Phys.*, vol. 32, p. 794 (1925).
[32] *Zeit. f. Phys.*, vol. 32, p. 841 (1925).
[33] *Zeit. f. Phys.*, vol. 33, p. 345; vol. 34, p. 296 (1925).

both equal to n, k of an electron already present), will contain deep-lying terms for which $r=R\pm\frac{1}{2}$, and l has the several values, $|L-k|+\frac{1}{2}$, $|L-k|+\frac{3}{2}$, . . . $L+k-\frac{1}{2}$.

The theory has been applied in great detail by R. H. Fowler and D. R. Hartree[34] to the spectrum of ionised oxygen (O II), and the terms to be expected on the theory have been found to be in very satisfactory agreement with the numerous regularities deduced from the analysis of the observed spectrum.

By the application of these methods it has been possible, as indicated in Table IX, to determine the probable ground terms of elements for which the spectra have not yet been classified, or even for which no spectroscopic observations are available. In cases where the arrangement of electrons is most doubtful, such as osmium and iridium, on account of the near equality of energies of different configurations, alternative arrangements and ground terms are suggested. The precise arrangement in such atoms can be decided only by further discussion of the spectroscopic data.

Grimm and Sommerfeld[35] have drawn attention to two general rules, namely: (1) All elements with completed sub-groups ($n_{kk'}$) of electrons have ground terms with $j=0$. (2) The element which immediately precedes or follows one that completes such a sub-group has a value of j for the ground term identical with the inner quantum number (k') of the sub-group to which the last bound electron belongs ($=k'$ for odd, and $k'-\frac{1}{2}$ for even multiplicities). Mg (12), for example, has $^1S_0$ for the ground term, while the preceding element, Na (11), has $^2S_{\frac{1}{2}}$ corresponding with 3_{11}, and the following element, Al (13), has $^2P_{\frac{1}{2}}$ corresponding with 3_{21}. In these simple spectra we also have $l=k$, but, as already indicated, this does not hold for complex spectra. A partial exception to the second rule is apparently found in comparing Rh (45) with Pd (46), but it is to be noted that there is a discontinuity in the succession of configurations at this part of the table.

There can be little doubt, however, that the foregoing table of electron arrangements and ground terms is substantially correct, and it may accordingly be utilised in the consideration of such questions as that of chemical valencies. In the paper above mentioned, Grimm and Sommerfeld have discussed the closing of sub-groups in relation to valencies, and have concluded, among other things, that the completion of the shell of two electrons must be taken into account, as well as that of the shell of eight which occurs in the inert gases. Attention is also directed to the elements copper, silver, and gold, which are of special interest because they immediately follow nickel, palladium, and platinum, respectively, these being the last of the 'triad' elements of Group VIII for which completed shells of eighteen electrons might have been expected. The position with regard to silver is quite clear, because it has been found that palladium has a ground term $^1S_0$, lying considerably below other levels, and implying a completed shell more or less resembling that of the inert gases. Thus the silver atom, with one additional electron, behaves essentially like the alkali metals, which have underlying completed groups or inert gas shells; silver is correspondingly always

[34] *Proc. Roy. Soc.*, A, vol. 111, p. 83 (1926).
[35] *Zeit. f. Phys.*, vol. 36, p. 38; *Nature*, vol. 117, p. 793 (1926).

monovalent, and its spectrum contains relatively few arc lines which have not been classified in the system of doublets. The spectrum of copper, on the other hand, is more complex than that of silver; in addition to a doublet system similar to the doublets of the alkalis, it shows many lines of a quartet system. The underlying shell cannot therefore be always completed, and it must be assumed that, in addition to the valence electron, one or more of the underlying electrons is easily displaced, giving an uncompleted group resembling that of nickel, which has a $^3F_4$ term for ground term. The two valencies are probably to be accounted for in this way. A similar argument applies to gold, which is monovalent and trivalent, since the preceding element, platinum, has a ^3D term for ground term, and the spectrum also is of greater complexity than that of silver.

An outstanding difficulty in connection with the scheme of atomic structures embodied in Table IX is that the azimuthal quantum numbers of Sommerfeld's theory of the regular X-ray doublets correspond with inner quantum numbers, and not with the azimuthal quantum numbers of the levels indicated. The difficulty is further emphasised by Millikan and Bowen's[36] important discovery that the regular doublet law is valid also in the optical doublet and triplet spectra, which they have especially investigated in the extreme ultra-violet, and by the further work of Landé[37] on the same subject.

An important step towards the removal of this and other theoretical difficulties, however, appears to have been taken by Uhlenbleck and Goudsmit[38] in a consideration of the possible effects of a rotation, or spin, of each electron. In further developments of the theory by Heisenberg and Jordan,[39] it has, in fact, been found that the 'spinning electron,' combined with the 'new quantum mechanics' previously initiated by Heisenberg, is competent to explain why the relativity doublet occurs between two levels that differ in their inner quantum numbers, and not, as in the original theory, in their azimuthal quantum numbers. At the same time, it may be noted, the conception of a spinning electron suggests a modified view of the fine structure of the hydrogen lines, which has been further developed by Sommerfeld and Unsöld[40] and appears also to be capable of giving an explanation of anomalous Zeeman effects.

The extraordinary theoretical developments in recent years, leading to the prediction of certain features of the spectra of elements and the structure of atoms, have possibly overshadowed the progress in experimental spectroscopy. Nevertheless, much experimental work of immediate importance to theory has been carried on, and much more is urgently called for. It must not be forgotten that, notwithstanding their general probability, the adopted electron configurations and the spectroscopic terms which are deduced therefrom are by no means all finally established. The theory is at present largely empirical, and important modifications may be demanded when the structures of other spectra have been determined. Indeed, there are relatively few spectra for which the analysis

[36] *Phys. Rev.*, vol. 24, p. 209 (1924).
[37] *Zeit. f. Phys.*, vol. 25, p. 46 (1924).
[38] *Nature*, February 20, 1926; see also Thomas, *Nature*, April 10, 1926.
[39] *Zeit. f. Phys.*, vol. 37, p. 263 (1926).
[40] *Zeit. f. Phys.*, vol. 36, p. 259 (1926).

can be regarded as complete, and many which have not been explored at all. Naturally, the spectra in which the regularities have not yet been traced are those which present special experimental difficulties. The spectra of some of the rare earths, for example, consist of a vast number of lines, and the determination of their structure will be extremely laborious, demanding in the first instance great accuracy in wave-length measurements. On the other hand, boron presents a difficulty because its lines in the ordinary region of observation are too few for complete classification. Very little is known also of the structure of the spectra of the halogen elements, and much work remains to be done on the classification of the lines of some of the inert gases, in continuation of Paschen's masterly analysis of the spectrum of neon.

Furthermore, predictions which can be made remain to be tested; for example, the spectrum of doubly-ionised scandium, which, in opposition to earlier expectations, should not resemble that of neutral potassium, is as yet unknown. Results of great importance to theoretical progress with respect to atom building may confidently be expected also from investigations of the spectra of other elements at successively higher stages of ionisation, as witness the results already obtained for the spectra of numerous elements in which the outermost shells of the atoms have been reduced to a single valency electron.[41]

The present resources of experimental spectroscopy would appear to be adequate for the elucidation of the majority of the outstanding problems. For most elements the conditions of excitation can be so modified that the spectrum is well under control, so that all the lines, or only a selection of them, can be produced at will. In the discussion of regularities it is, in fact, often required to excite the complete spectrum, including the fainter lines, for the completion of multiplet groups. On the other hand, as an aid to the determination of ground terms, one desires to produce the smallest number of lines that an element can be induced to give.

The old, well-tried methods of exciting substances to luminosity—the flame, arc, spark, and vacuum tubes—have by no means been superseded. They provide the observer with a wide range of exciting energies, and seem likely to continue long in use as standard methods applicable to most of the elements. While the flame yields only the lines representing combinations with the deepest terms of the spectrum, the spark with some elements, such as silicon, is capable of exciting even trebly-ionised atoms, and it is usually possible to sort out the lines associated with atoms at different stages of ionisation by merely observing the extensions of the lines from the tips of the electrodes. Experiments on the absorption spectra of metallic vapours will no doubt also continue to be of effective service in the identification of lines which originate in the normal atomic energy levels, or in the verification of deductions as to the normal states based upon analyses of the more complex emission spectra.

The older methods of observation, however, have been supplemented by numerous other experimental arrangements. Some of these, like the

[41] A. Fowler, *Phil. Trans.*, A, vol. 225, p. 1 (1925). Millikan and Bowen, *Phys. Rev.*, Sept. 1924; *Phil. Mag.*, May 1925. J. A. Carroll, *Phil. Trans.*, A, vol. 225, p. 357 (1925). D. R. Hartree, *Roy. Soc. Proc.*, A, vol. 106, p. 552 (1924).

electric furnace so effectively employed at Mount Wilson by A. S. King, have brought the spectrum of an element under more gradual control, so that a valuable aid in the classification of the lines of a complicated spectrum is provided by the order of their appearance as the temperature is raised. From other experiments by A. S. King,[42] it would appear that an arc with a current of the order of 1,000 amperes, at 100 volts, has the advantage, from the present point of view, that it exhibits with relatively greater intensity the high temperature lines which are weak in ordinary arcs; moreover, the fact that the widenings and reversals of lines, which are a prominent feature of this kind of arc, are of the same type in the same multiplet, promises to be of distinct value in the analysis of complicated spectra.

A valuable method of producing or modifying the spectra of certain gases by admixture with helium was introduced by Merton[43] in his experiments on the band spectrum of hydrogen. Among the most remarkable results obtained by this method was the production, almost free from enhanced lines, of spectra attributed to atoms of neutral carbon and neutral nitrogen when a trace of one of these elements was present in helium at a pressure of several centimetres.[44] Little was previously known of these spectra, apparently because carbon compounds and nitrogen, in ordinary vacuum-tube observations, mainly break down directly from the molecular state (giving band spectra) to ionised atoms, the spectra of which were already well known. Other observations have shown that while the presence of helium is not essential for the development of these spectra, the mixture method has the advantage of bringing out the lines with greater completeness and intensity.

A further important application of this method to oxygen has been made by McLennan and Shrum,[45] resulting in the appearance of a previously unrecorded oxygen line at 5577·35, apparently agreeing in position with the well-known green line in the spectrum of the aurora. Here again, the line could be obtained, but with much lower intensity, in the absence of helium. A continuation of the experiments may be expected to reveal other members of the singlet system, which probably forms part of the spectrum of oxygen in company with the already known triplet and quintet systems.

Among numerous other methods of controlling the spectra of certain elements which have been successfully adopted, it will suffice to mention the electrodeless 'ring discharge' of Sir J. J. Thomson, in which different spectra of the same element may be excited by varying the voltage and the pressure in the bulb or tube. Zeeman and Dik,[46] for example, in this way obtained the second spectrum of potassium entirely free from arc lines, and, as expected from the displacement law, found it to be of the same general character as that of argon. McLennan[47] similarly found it possible to obtain spectra of potassium apparently corresponding to the

[42] *Astrophys. Jour.*, vol. 62, p. 238 (1925).

[43] *Roy. Soc. Proc.*, A. vol. 96, p. 382 (1920).

[44] Merton and Johnson, *Roy. Soc. Proc.*, A. vol. 103, p. 383 (1923). Merton and Pilley, *Roy. Soc. Proc.*, A, vol. 107, p. 411 (1925).

[45] *Roy. Soc. Proc.*, A, vol. 108, p. 501 (1925).

[46] *Proc. Kon. Acad. Amst.*, 1922, 1925.

[47] *Roy. Soc. Proc.*, A, vol. 100, p. 182 (1921).

'red' and 'blue' spectra of argon. By using a cylindrical tube for this form of discharge, L. and E. Bloch[48] were able to distinguish the lines of mercury representing the first and second stages of ionisation by observing the extension of the lines from the edges towards the centre; and in the same way, Esclangon[49] has sorted out lines attributed to four successive spectra of cadmium.

Some of the newer methods have definitely brought additional spectra within the range of laboratory experience. Thus, by electric bombardment of lithium at a temperature of 1,000 deg. C., Werner[50] succeeded in producing the spectrum of ionised lithium, which had resisted all attempts to obtain it by ordinary spark discharges. In accordance with theoretical expectation, the new spectrum was resolvable into series having 4R for the series constant, and was found to correspond closely with the spectrum of neutral helium. A similar, but less complete, spectrum of ionised lithium was also obtained by Schüler,[51] who made use of the 'hollow cathode' method, and by Morand[52] with an apparatus in which the metal was excited by anode rays.

One of the few sources which can at present be employed for observations in the extreme ultra-violet is that known as the 'vacuum spark,' which has been extensively utilised by Millikan[53] and his colleagues. In this method the spectrograph and spark chamber are highly evacuated, and a powerful spark is made to pass between electrodes separated by one or two millimetres or less. The spectra include lines representing various stages of ionisation in a single photograph, but their disentanglement can be effected with the help derived from the analysis of spectra obtained under better controlled conditions in more accessible regions. The interpretation of such spectra, however, has been greatly simplified by the recent remarkable work of Bowen and Millikan,[54] who, by utilising high orders of the grating, have obtained a high degree of resolution of complex groups, and wave-lengths of a degree of accuracy approaching that obtainable in ordinary parts of the spectrum.

Another class of 'experiments,' as I have previously mentioned, is provided by the heavenly bodies. Saha's theory of high-temperature ionisation, further developed by Fowler and Milne[55] and by Miss C. H. Payne,[56] has already been utilised in the prediction of the ionisation potentials of certain multiply-ionised atoms for which the structures of the corresponding laboratory spectra have not yet been sufficiently determined to indicate the energies of the normal states. In this way it is conceivable that we may obtain approximate values of the actual energy levels in some of the complex atoms for which only relative values can at present be directly determined from the spectra.

[48] *Jour. de Phys.*, vol. 4, p. 333 (1923).
[49] *Dissert.*, Paris, 1926.
[50] *Nature*, vol. 115, p. 191 (1925).
[51] *Die Naturwiss.*, July 11, 1924.
[52] *Comptes Rendus*, vol. 178, p. 1528 (1924).
[53] *Astrophys. Jour.*, vol. 52, p. 47 (1920), etc.
[54] *Phys. Rev.*, vol. 26, p. 150 (1925).
[55] *Mon. Not. R.A.S.*, vol. 83, p. 403 (1923); vol. 84, p. 499 (1924).
[56] 'Stellar Atmospheres,' *Harvard Obs. Monographs, No. 1* (1925).

Apart from the question of sources for spectroscopic study, Zeeman effects, with the rules of Landé[57] for their interpretation, provide the observer with a powerful means of determining the types of terms in many spectra.

Enough has been said, I hope, to give some idea of the main lines of development and present trend of spectroscopy. The analysis of spectra with which I have been chiefly concerned is a fascinating pursuit, and the establishment of a beautiful order out of an apparent chaos of spectrum lines brings great satisfaction to the investigator. I have endeavoured to show, however, that the analysis of spectra is not an end in itself, but that under the guidance of quantum theory it has fundamental contributions to make to our understanding of atomic structure and of the periodic classification of the chemical elements. It appears not at all improbable that some of the mysteries of chemical valency may also find a solution in the classification of spectrum lines, and there are indications that the conceptions of spectroscopy may ultimately extend our knowledge of the structure of matter in the liquid and solid states.

It may be that in the future the theory of spectra will be so far developed that it will become possible to calculate the positions and intensities of the lines composing the spectrum of an element with greater accuracy than they can be observed. We are, however, still very far from this ideal, and meanwhile experiment and theory must go hand in hand towards a better understanding of the problems that lie immediately before us.

[57] Back and Landé, *Zeemaneffekt und Multiplettstruktur*, Berlin, 1925.

SECTION B.—CHEMISTRY.

THE SCOPE OF ORGANIC CHEMISTRY.

ADDRESS BY

PROF. J. F. THORPE, C.B.E., D.Sc., Ph.D., F.R.S.,

PRESIDENT OF THE SECTION.

The chemistry of the compounds of carbon covers a wide field, wider than that covered by any other element. Its scope embraces all living matter, as well as the vast number of non-living substances which are produced through the agency of life. Moreover, it includes a very great number of compounds unrelated to life or to living processes which have been built up by the chemist in the laboratory by methods he has devised.

Already some 200,000 definite compounds have been tabulated in Richter's Lexicon and in the supplements thereto, and this number is increased yearly by several thousands through the agency of a band of zealous workers scattered over the globe. It may well be asked what is the good of continuing to increase this already astonishing number; and is the expenditure of time, labour and energy justified which leads to the discovery of some new fact having, apparently, no useful application to any department of human activity? The answers to these questions are quite clear and definite. You must acquire a knowledge of the simple before you can attack the complex with any hope of success. The element carbon has been used by nature as the basis of organised life because the capacity of carbon to combine with itself is shared by no other element, and it is upon this capacity that nature has relied in order to build up the tissues and reserve materials which form the living world around us. Moreover, since the compounds of carbon containing a moderate number of atoms of the element are usually crystalline or capable of becoming crystalline, and there are obvious disadvantages attaching to the use of potentially crystalline substances as the basis of living matter, it has been found necessary to employ the more complex carbon derivatives containing many hundreds of elemental atoms, which by reason of their high molecular complexities no longer possess, or seem capable of acquiring, a crystalline structure, but belong to the class of jelly-like or colloidal substances. Until we can determine how a small number of carbon atoms combine one with the other we cannot hope to obtain any insight into the manner in which the more complex natural substances are built up, or any information regarding the way in which they are utilised to bring about the changes occurring during animal and vegetable metabolism.

Structure.

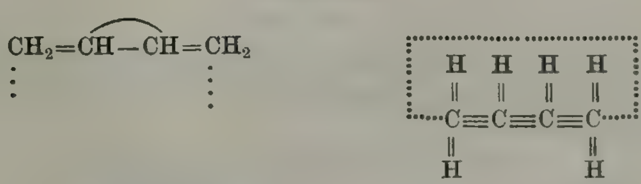
The science of structural organic chemistry is only just fifty years old. It was born when the genius of van't Hoff gave to the world the clue upon which the three-dimensional formula we now use is based. It is, therefore,

no inconsiderable achievement to have gained in so short a time a knowledge of many of the reactions and properties of the more simple complexes of carbon in combination with oxygen, nitrogen, and other elements. But much yet remains to be done before we can attack with any real hope of success the problems which the chemistry of nature presents. It is true that the knowledge already gained has led to the synthetic preparation of quite a number of natural products, many of which are of service in relation to human needs. Many of the alkaloids, colouring matters like indigo and alizarine, camphor, and a large number of natural products, have yielded the secrets of their structures and have been produced by laboratory methods and, where necessary, on the factory scale. But the synthesis of such compounds has not provided much insight into the mechanism leading to their production in nature, and, indeed, the reason for their occurrence in the plant is not understood. They are, moreover, crystalline substances which either occur in the plant as such or are formed by the hydrolytic fission of some more complex plant materials. Their homogeneity is, therefore, not open to doubt, and their degradation into known fragments and the rebuilding of these fragments into the original substances, although by no means easy, is nevertheless comparatively simple when the difficulties attending the investigation of more complex natural products are taken into account. Even so, some of the simpler type, for example, strychnine, still resist the attack of the chemist.

The Electronic Theory.

It is clear that our knowledge of the finer mechanism of reactions is slight, and that, great as has been the advance made through the discovery of van't Hoff, we are still at a loss to explain or predict the shades which determine whether one particular type of reaction will be more, or less, facile than another. The chief trouble seems to be that the electronic theories, which are quite satisfactory in themselves, are not yet developed so fully that they can include any quantitative statement relating to the changes in the free energy of systems. Yet it is evident that any theory of organic structure must conform to the modern physical conceptions of matter. The principle of shared electrons is primarily justified by its success in explaining the linking of atoms, *i.e.* valency, and by its successful interpretation of the theory of co-ordination and ' onium ' salt formation. The subsidiary hypothesis of electron displacement also provides a means by which an explanation can be supplied to account for the ease of formation, stability, and general reactions of conjugated systems, thus placing the hypothesis of Thiele on a sounder theoretical basis.

Butadiene.



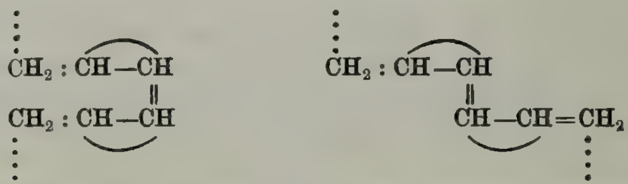
(Thiele.) (Electronic formula.)

In the formula for butadiene shown above, the dotted line indicates the interchange of an electron between the two end carbon atoms of the system; it is to be assumed that this condition provides a point of attack and leads to the 1 : 4 addition which is characteristic of this substance. Evidence has been sought in order to substantiate this view, and with this object an extended investigation on the properties of hexatriene has been undertaken.

Hexatriene contains a three-conjugated system, and must, in accordance with stereo-chemical theory, exist in two forms, which may be represented diagrammatically thus:

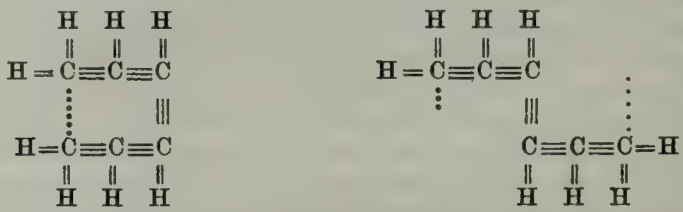
(cis.) (trans.)

In accordance with the Thiele hypothesis these would be conjugated thus:

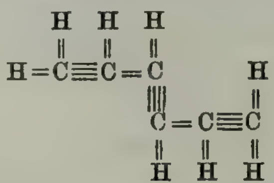


and there should thus be no difference in the behaviour of the two forms towards additive reagents such as bromine.

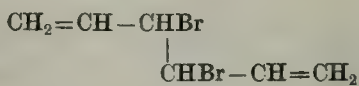
On the other hand, if these two forms are expressed in terms of the electronic hypothesis thus:



the cis form, in which the two terminal atoms are near together, might be expected to share the electron, as shown by the dotted line, whilst the trans form, having the terminal carbon atoms too remote from one another to enable this interchange to take place, would react in the form



There can be no doubt that the hexatriene prepared by van Romburgh is the trans form. This, as its discoverer showed, adds on bromine in the positions 3 : 4 to give



It is, therefore, not a conjugated system in the sense that butadiene is a conjugated system.

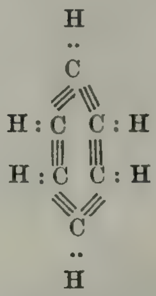
We have now succeeded in isolating cis-hexatriene, and are studying the action of bromine on it. If, as is to be anticipated, the addition takes place in the 1 : 6 positions, direct evidence will be available in favour of the electronic hypothesis. The work is, however, exceedingly difficult because, unlike those of the trans series, the cis compounds are liquids and therefore difficult to identify. Moreover, they are unstable and readily polymerise to resins on keeping. There is no doubt, however, that these difficulties will be overcome.

In the same way the Thomson[1] formula for benzene provides an expression for the intermediate state as postulated by Kekulé, and renders the so-called centric formula, which is meaningless, now unnecessary.

BENZENE.

(Kekulé.)

(Centric.)



(Thomson.)

There can be no question that the distribution of electrons among the carbon atoms and other atoms of organic molecules must determine the reactions of the complexes involved, and future research will no doubt lead to an advance in our knowledge concerning the causes which promote or retard this distribution.

The ductility of the carbon to carbon bonds which have now been clearly demonstrated enables us to impart strains to certain parts of an organic molecule at will, and it is reasonable to assume that such strain when once set up will be shared as far as possible equally by all the atoms of the system involved. If this distribution is, as Robinson postulates, effected by a restricted flow[2] of electrons from one atom to another in the molecule, we have, at any rate, a definite picture of the process which the mind can grasp ; and if the distribution leads ultimately—as is to be surmised—to the establishment of polar characteristics at different parts of the molecule, which will determine reactivity at those points, we are in a fair way to reconcile the views of various contending schools and to reach a general hypothesis acceptable to all chemists, and which may even satisfy the physicists. It seems that, despite the organic chemist's proneness and ability to distort the molecules with which he deals, nature has provided a means by which a certain degree of molecular equilibrium can be attained. Nevertheless it will be by the investigation of the conditions leading to the setting up of strain and of the effect produced

[1] See also H. Kauffmann (*Die Valenzlehre*, 1911, p. 539).

[2] Robinson considers that an electron may leave its 'moorings' on one of the atoms which holds it but never on both.

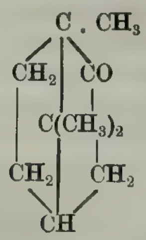
thereby that we shall gain the most information regarding the chemistry of carbon structures in the near future. The course of a reaction in organic chemistry which involves an equation such as the following

$$CH_3.CH_2.CH_2Br + CHNa\begin{matrix} \diagup COO\ Et. \\ \\ \diagdown COO\ Et. \end{matrix}$$
$$\rightarrow NaBr + etc.$$

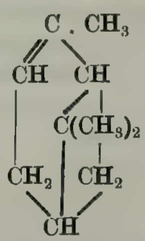
is determined by the tendency to form NaBr—the organic residues have to make the best they can of the situation, and the manner in which they will combine with themselves or react each with the solvent is dependent on the influence of many factors. Undoubtedly there will be a tendency to produce the most stable system and the one whose formation involves the greatest loss of free energy, but there must be a possible mechanism, and this involves the polar factors. Even these cannot force a group into a position in which there is no room for it, and therefore the effect of polarity must always be dependent on steric conditions. No doubt polar conditions determine the order of priority of a number of possible arrangements, but it is the steric condition that determines which of these arrangements shall be followed.

Strainless Systems.

It is reasonable to assume that the organic substances that occur in nature as such are produced by means which involve the least expenditure of energy, and that they are, therefore, strainless. Among such natural products there are many containing carbon rings belonging to ring systems which cannot normally be produced without distorting the carbon tetrahedral angles of the component carbon atoms, and thus imparting intramolecular strain to the compounds formed. Nevertheless it is interesting to note the means adopted by nature to relieve this strain and thus to confer equilibrium and stability on quite unlikely ring systems. Ring systems stabilised in this way are found frequently among terpenes; two, namely camphor and pinene, need only be mentioned to illustrate the general method. In camphor the bridged ring is stabilised by the presence of two dimethyl groups, and in pinene, where the junction of the inner ring has to take effect in the position 3, the presence of a double



(Camphor.)



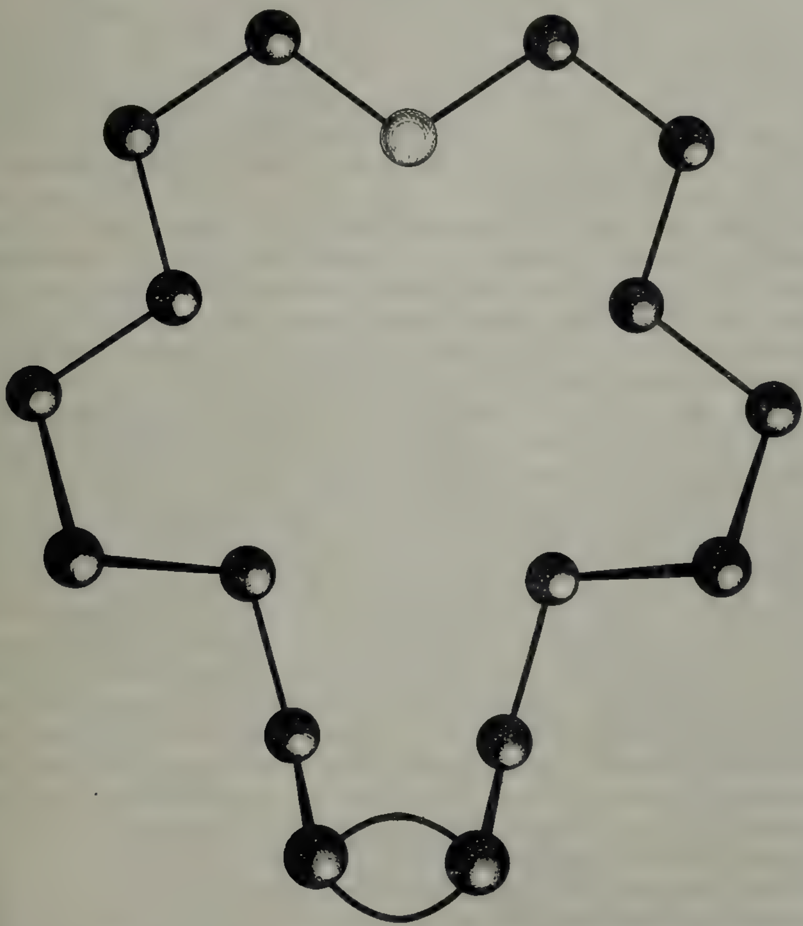
(Pinene.)

bond on the shoulder of the external ring is necessary. Still more remarkable examples are afforded by more complex natural ring systems. For instance, there is a substance named civetone, which is extracted from

certain glands of the Civet-cat. There is no doubt as to its structure, which has been shown to contain a 17-membered ring, thus :

$$\begin{array}{l} CH.(CH_2)_7 \diagdown \\ \| \qquad\qquad\qquad\quad CO \\ CH.(CH_2)_7 \diagup \end{array}$$

the evidence of structure being derived both from a study of the degradation products of the substance and also by its recent synthesis. If this compound is set up on the tetrahedral models, thus :



it will be found to form a triplanar figure which is strainless ; the condition being produced by the presence of the double bond in the position shown.

Biochemistry.

In its earliest days the science of organic chemistry dealt only with those compounds which were derived from natural sources, and it was regarded as certain that such substances could only be produced through the agency of life and by no other means. Since then this theory has been shown to be wrong by the preparation in the laboratory of many substances identical with those formed during the operation of life pro-

cesses. Nevertheless, the more complex substances which nature utilises in building up her animal and vegetable structures still show no signs of yielding the secrets of their constitutions, or the mechanism by which they are produced. Indeed, although we can imitate in the laboratory certain natural operations such as the hydrolysis of starch to glucose, we are still quite ignorant of the means by which glucose is converted, by the appropriate enzyme, into alcohol and carbon dioxide, neither can we imitate this process in the laboratory.

When once the chemist has passed beyond the crystalline and the distillable he enters a region full of difficulties, because he has few means either of purifying the materials with which he has to deal, or of determining their homogeneity when they have been purified. These are the real difficulties which confront the biochemist when he approaches his subject from the structural side of organic chemistry. Biochemistry is in the unique position of being both a descriptive or observational science and also one of the experimental sciences. From the biological side it has at its disposal the wealth of knowledge acquired by the physiologists and pathologists, and from the chemical side it is in touch with the recorded experience of several generations of organic chemists. If biochemistry is to justify its name it must carry out its function of bringing into line the discoveries of the physiologists with organic chemical structure, for by this means only will it be possible to gain an insight into the chemistry of natural processes which it is the object of biochemistry to discover. It is far from my object to disparage the wonderful work which has been done and is being done by physiologists and pathologists in their attack on the mechanism of normal and abnormal life processes. Their record speaks for itself. But too little is being done to approach the problems from the purely organic chemical side, and too few of the people engaged in biochemical research have an adequate knowledge of organic chemistry or the methods of the organic chemist. The number of organic chemists who are co-operating with biologists in their attack on natural processes is too few. Indeed, the very difficult question arises here as to how best to organise methods for dealing with problems which are essential borderland problems between two great sciences. I do not propose on this occasion to discuss the vexed question of the chemical engineer, but actually the analogy between this hybrid and the biochemist is fairly close. Is the biochemist to be a biologist with a knowledge of chemistry, or is he to be a chemist with a knowledge of biology? I refer, of course, to the method of training required for a man or woman who proposes to take up biochemical research during the fourth year. Given twenty years and the requisite capacity it is, of course, possible for a man to acquire sufficient acquaintance with both sciences to render him an effective worker in the borderland field, although here again the temperament which promotes enthusiasm for research in the experimental sciences and that which leads to initiative in the descriptive sciences is not usually found in the same individual. As knowledge increases the need for specialisation must also increase, because the time factor—that is, the time during which it is possible for a student to undergo training—cannot be prolonged beyond a certain period. Even at the present time it is an open question whether it is possible to give a student a special training in more than one science

and in the sciences subsidiary thereto in the time available, and this problem will become more acute as knowledge increases. It has been suggested that we should revert to the older method by which a student was instructed in, say, three sciences without any special training in any one of them, and doubtless this method was a good one for the requirements of those times. But the day of the universalist is past, and general scientific culture has become a luxury of the leisured classes. It is only by the aid of the specialist that, nowadays, we can hope to obtain advances in knowledge either in the sciences or in the sciences applied to industry.

It seems that the best method to attack problems in the borderland subjects is by co-operation between two types of trained investigators. In the case of biochemistry, for example, by the provision of trained students of two kinds, the one trained in physiology but with a sufficient knowledge of organic chemistry to promote sympathy with and knowledge of the chemist's point of view, and the other trained as an organic chemist with a similar knowledge of the methods and requirements of the physiologist. The former would be a trained physiologist who would devote his final year to organic chemistry, the latter an organic chemist who would devote his final year to a study of physiology. This is, of course, no new idea, but one which is being carried out in at least one institution in this country in connection with other borderland subjects. But it is the absence of any real attempt to approach biochemical problems from the chemical side that renders it particularly desirable that the need for some such scheme should be emphasised. It is true that the fault is largely on the side of the organic chemists, who, for the most part, seem appalled by the difficulties attaching to the study of natural processes. The difficulties are indeed great, but not insurmountable. We are far from gaining any insight into the meaning of life, but it is not unlikely that we shall, in the near future, obtain some information regarding the mechanism of the action of the enzyme, the important agent in the non-living transformation of living matter into chemical products. It may be that organic chemists are waiting to see how Willstätter, who has already made great progress in enzyme chemistry, will surmount the difficulties confronting him, and it may well be that this great organic chemist will introduce new methods of attack which will open up fresh fields for investigation.

Analytical.

Except for the substitution of gas for charcoal, it cannot be said that the ordinary methods of analysis employed by the organic chemists have changed much since the days of Liebig. They have been modified, notably by Dennstedt, and more recently some have adopted the micro-chemical methods introduced by Pregl, but the older methods, for example the long and tedious process for the estimation of halogens by the method of Carius, are still in vogue in many of our laboratories and are taught to the students. In any case the usual operations entailed by the estimation of carbon and hydrogen, nitrogen, sulphur and the halogens require considerable time, which has not been materially shortened by the introduction of the less cumbersome methods due to Dennstedt. Pregl's methods, in which a very small quantity of material is used requiring

the provision of a special type of balance, have been tried in many laboratories, and have found favour, it is understood, in several of them, more particularly abroad. But the general experience has been that the technical skill required to obtain good results is acquired only after long practice, and that whereas the methods are useful for gaining an indication of structure when the quantities of material at hand are so small as to necessitate their use, yet when a sufficient quantity of substance is available the older methods are more reliable and more easily carried out. It is interesting to note that the new methods which have been introduced by Prof. ter Meulen, of Delft, are going to be described to us by Prof. ter Meulen himself, who is fortunately with us at this meeting. Prof. ter Meulen will give an account of his methods on Tuesday morning, and they will be shown in actual operation during the soirée on Tuesday evening. Chemists will then see that a great saving of time can be effected by methods which can not only be used to analyse the small quantities employed by Pregl, but also quantities of 0.1 grm., such as organic chemists have been accustomed to use in the past, and which have been shown to produce the most accurate results.

The Utilisation of Forest Products.

The immense number of organic compounds distributed among the plants, trees, and grasses which form the forests and jungles of the world offer a wide field for research which has still much to yield. Our knowledge of the medicinal properties of organic substances and the various uses to which they could be put in the service of mankind did not come to us through any effort of the chemist, but as the outcome of a process of trial and error which is as old as the human race itself. These products were obtained from vegetable materials present in the forests, and as time went on they were extracted in a form possessing some degree of purity, and the plants containing those with specially valuable properties were cultivated for their production. As soon as a theory of organic structure was evolved upon which prediction could be based, these useful products were subjected to close investigation, and in several cases they were prepared by laboratory means. As an outcome several of them, such as indigo and alizarine, were found to be capable of production more economically by the chemical method than by the processes of life, and the natural substances were rapidly replaced by the artificial products. Others still resist all efforts to unravel their structures, and remain still unsynthesised. Nevertheless it has been by a study of the chemical structure of natural products that much has been learnt regarding the relation between chemical composition and physiological action, and although it may not have been found possible economically to prepare the natural substance itself, the clue revealed by the determination of structure has led to the production of other substances which have not only shown the properties of the natural compound in an enhanced form, but have also exhibited other valuable physiological effects. The determination of structure has, therefore, two objects—to prepare the natural substance and to ascertain the particular arrangement of the atoms in the molecule which confers on it the properties which determine its value. The determination of the structure of indigo led not only to

the production of the blue natural indigo, but enabled indigoes of every shade of the spectrum to be prepared as commercial products. The determination of the structure of cocaine revealed the molecular complex which conferred on this substance its power to act as a local anæsthetic, and has led to the production of a number of other substances possessing this valuable property, but without the special disadvantages attaching to the use of the natural substance. Examples of this kind are numerous and should be increased. A systematic examination of our forest products would undoubtedly lead to the discovery of many others, and would provide opportunity for the investigation of many other important problems, such as, for example, the utilisation of forest grasses as a source of power alcohol.

Systematic team-work research by organic chemists in close association with botanists is required, and now that the Forest Production Research Board of the Department of Scientific and Industrial Research is in active operation, no doubt this branch of its work will receive attention.

Petroleum.

The complex hydrocarbons which form the main constituents of crude petroleum belong to a section of organic chemistry at present too little explored. Although many millions have been made through the production and sale of petroleum products, it is safe to say that the percentage of profit devoted to research in oil products has been infinitesimal. It is true that in the United States large sums are given by the oil interests towards research in other subjects, but until quite recently none of these was, curiously enough, given for the purpose of improving our knowledge of the science on which the utilisation and isolation of petroleum products depends. The reason is not far to seek. The apparently inexhaustible supplies of petroleum rendered it unnecessary to devise means for economical working. The crudest and most wasteful methods were employed, because economy and the conservation of the natural product were not paying propositions. This applies not only to the methods used in fractionisation, but to those employed for the purpose of 'cracking' the higher boiling fractions into liquids of lower boiling-point. For at the present moment it is the fraction up to 200° C. which is the important product, because it is the 'petrol' of the internal-combustion engine. Time was, before the introduction of this particular machine, when the light fraction from crude petroleum was a drug on the market, and in many cases was actually set on fire at the refinery because no use could be found for it. In those days the chief product was the kerosene fraction which was used as lamp-oil. At the present time the rapid increase in the use of the motor-car for personal and commercial transport indicates that at no distant period, if progress continues to be made in the same direction, the amount of the 'petrol' fraction will be insufficient for the world's needs. This point has already been reached in America, where approximately 70 per cent. of the world's consumption of petrol (gasoline) is effected. During 1925 the consumption of petrol in the U.S.A. approached 800,000,000 gallons a month, which is about twelve times the amount consumed in this country. It has been stated that one in every five persons in the States—men, women, and children—possess a

motor-car,[3] and, be this as it may, it is evident that to meet such a colossal consumption means have to be found to utilise the higher boiling fractions, and, indeed, even the residues from the distillation processes. This 'cracking' operation is now carried out on an enormous scale by numerous processes, all subject to patents, but differing from one another only slightly on the question of principle. All depend on the well-established fact that hydrocarbons of high molecular weight will break down into those of lower molecular weight if they are subjected to the requisite degree of temperature. Pressure appears to play an important part in the character of the product, as does also the surface action of the container or material used in the container to promote surface action. All are wasteful, because little or no research has been carried out on the true chemical nature of the cracking operation. Much permanent gas is always produced, consisting for the most part of ethylene and propylene. In the States the ethylene is allowed to go free, because its obvious utilisation in the form of ethyl alcohol is attended with difficulties, but the propylene is usually absorbed in sulphuric acid, and thus converted into *iso*propyl alcohol, useful as a solvent. The production of these two unsaturated hydrocarbons provides a clue to the mechanism of the cracking process which is of some significance. If you break a long chain-saturated hydrocarbon one of your products must be an unsaturated hydrocarbon, and it is evident that cracked spirit contains a considerable proportion of such unsaturated bodies. Moreover, the cracking processes at present in use do not produce aromatic hydrocarbons, and it is on the presence of a proportion of these aromatic hydrocarbons that certain special properties of petrol depend. For example, the tendency at the present time is to produce for motor-cars internal-combustion engines of increased compression ratio, in order mainly to diminish the petrol consumption and thus increase mileage per gallon consumed. For some reason, which research has not yet ascertained, the use of petrol which does not contain the right quantity of aromatic hydrocarbons of the benzene type leads to 'detonation,' 'knocking,' or 'pinking' when ignited in cylinders giving more than a small compression ratio. This detriment diminishes the value of cracked spirit as such for any but low-compression engines, and many have been the devices suggested in order to overcome this difficulty. A vast number of substances, selected more or less at random, have been tried as 'anti-knock' materials, and as an outcome it has been found that one, namely lead tetraethyl, possesses the property, when present in exceedingly small quantities, of preventing the 'detonation' of the explosion mixture in the cylinder. For a time lead tetraethyl (ethyl gas) fell under a ban in the States owing to a fatal accident which attended the spilling of a certain amount in one of the American factories, but it is understood that further investigation has led to a revision of the view first formed, and that considerable quantities of 'ethyl gas' are now being used. The writer remembers visiting Wilmington in 1924, when some 500 gallons of lead tetraethyl were being made daily. Although there was naturally a strong smell of the material in the factory building, and he remained for some hours there, no ill-effects were noticed. It is

[3] Cars registered on January 1, 1925, were: U.S.A., 17,591,981; Canada, 638,794; Great Britain, 1,094,534.

obvious that the conditions which produce 'knocking,' and the reason why certain substances are 'anti-knock' compounds, and why the presence of aromatic hydrocarbons prevent the phenomenon, must be made the subject of systematic research.

The question is also one of national importance, because in the case of high-compression engines, such as those used in aeroplanes, it is essential that a petrol should be used containing a high percentage of aromatic hydrocarbons. In war-time these aromatic compounds will be required for the manufacture of explosives, and it is quite certain that there will not be enough for both purposes.

Nevertheless, it must be remembered that it is only at the moment that the low boiling fraction of petroleum is the chief marketable product. It is probable that progress in the future will tend more and more to produce a motor-car engine of the Diesel type, or one having a carburettor capable of effectively vaporising the higher fractions of petroleum. In these circumstances it may well be that the low fraction will become the less important part of crude petroleum, and that, instead of having to resort to 'cracking,' a process of synthesis, by which the lower hydrocarbons can be converted into higher ones, will have to be adopted. As a matter of fact there are methods known by which this can be effected. Pure *iso*amylene can, for example, be converted into diamylene by interaction with stannic or aluminium chloride, and the process can be carried further, so that perfectly good lubricating oils can now be made by the polymerisation of the lower unsaturated hydrocarbons.

Polymerisation and depolymerisation are, therefore, the two operations which the petroleum industry must investigate and establish on a firm scientific basis by research, so that it may be in a position to supply the public need for any particular form of engine which the engineer may evolve. Especially is it desirable to ascertain under what conditions polymerisation leads to the formation of aromatic and naphthenic hydrocarbons. Considerable attention has been drawn within recent times to what may be termed in general the Bergius processes for depolymerising organic substances. The operation, which consists in heating the material under high pressure in the presence of hydrogen, was introduced in the first instance for the treatment of coal. There can be no question that great and fundamental changes are brought about in organic substances by the treatment whether a catalyst is present or not, and that a wide field for research is opened up thereby, but it is doubtful if, at the moment, general operations of this type can be regarded as commercial propositions. The plant is exceeding costly and the conditions subject to wide variations which are difficult to control. Actually it has been ascertained that in the 'cracking' of the kerosene fraction of petroleum hydrogen is unnecessary, and can be replaced by nitrogen without affecting the character of the final product.

Little is known of the constituents of crude petroleum, or, indeed, of the fractions into which it can be separated after purification and distillation. Some of the simpler hydrocarbons of the pentane and hexane type have been isolated and the presence of cyclic compounds has been established. Many of them are classed under the head of 'naphthenes,' but these are of uncertain structure. No doubt many are present in the

crude oil, but it is certain that others are formed during the distillation process. It is clear that much opportunity for research work offers itself here, and it is probable that small alterations in the method of distillation may cause deep-seated changes in the character of the distillate, causing it to be of greater service for particular purposes. The occurrence of hydrocarbons of the naphthalene series in petroleum products has also been clearly established. The higher fractions which constitute the valuable lubricating oils also need attention, for it is now certain that viscosity bears no relation to oiliness, that is, the capacity for acting as an efficient lubricator. The addition of small quantities of 'polar' substances of the type of fatty oils or acids confers increased oiliness on these compounds, and although we are now gradually reaching a stage when we know more about the effects of such ingredients, the field for research is still a large and important one.

The formation of free carbon occurs during both the distillation and 'cracking' processes, in some cases to a very considerable extent. The utilisation of this carbon for the purposes of making electrodes is an important part of the industry, and the formation of carbon in a condition in which it can be used by the rubber-tyre manufacturers is also likely to become practicable as an outcome of the thermal decomposition of hydrocarbons.

At present we know nothing about the structure of the hydrocarbons present in the lubricating oils. Indeed, it seems possible that these may not be long-chain hydrocarbons with which the organic chemist is familiar, but rather polymerised products formed from unsaturated components liable to be formed or destroyed under comparatively mild conditions. The relative ease with which the oil in the engine sump of a motor-car loses its oiliness through continued use is not characteristic of the stability usually associated with an organic hydrocarbon. Recent researches on the formation of dimeric products of the simple type

$$\begin{array}{c} \mathrm{XCH{=}CHY} \\ \\ \mathrm{XCH{=}CHY} \end{array} \rightarrow \begin{array}{c} \mathrm{XCH-CHY} \\ |\qquad\quad| \\ \mathrm{XCH-CHY} \end{array} \text{ or } \begin{array}{c} \mathrm{XCH-CHY} \\ |\qquad\quad| \\ \mathrm{YCH-CHX} \end{array}$$

show that the ease of formation and stability of such systems depend on the composition of X and Y. In some cases stable complexes of this kind are formed which can be distilled without undergoing disruption, but which are broken down slowly on prolonged heating even at a moderate temperature.

In the complex hydrocarbons under discussion the letters X and Y represent hydrocarbon residues, probably themselves containing other unsaturated linkages, and under the conditions of high pressure which were probably present during the formation of natural petroleum it is possible many of these four-membered rings are formed in a single molecule, for example:

$$\begin{array}{c} \mathrm{XHC-CH-CH_2-CH-CHX} \\ |\qquad\ \ |\qquad\qquad\quad\ |\qquad\ \ | \\ \mathrm{YHC-CH-CH_2-CH-CHY} \end{array}$$

an expression which, incidentally, indicates the manner in which the cyclohexane complex can also be produced by a similar process. So far

as the chemistry of petroleum is concerned this is at present mere surmise, which must be investigated as soon as practicable. The view is, however, rendered plausible by the work which has been carried out at the Imperial College during the past five years, which shows conclusively that the formation and stability of ring systems depend on the character of the groups attached to the carbon atoms forming the rings, and are not merely dependent, as Baeyer supposed, on the tetrahedral angle of the carbon atoms involved. It is probable also that a similar explanation may account for the 'naphthenes,' and will provide a general explanation of polymerisation and depolymerisation upon which it will be possible to base improved technical processes.

The composition of petroleums varies in accordance with their origin. Some are rich in aromatic hydrocarbons, and some are practically sulphur free; others contain so much of the last-named element as to render them unfit for use. The Kimmeridge shale oils are instances of the latter type, although doubtless if it were a paying proposition the sulphur could be readily eliminated from these products. The oil from the Persian, Mexican, and Ohio fields contains sulphur, which has to be eliminated during the process of refining. Among the sulphur compounds present mercaptans and thioethers have been identified, although whether they are present in the crude oil as such or whether they are formed during the refining process is still an open question. Their removal by washing with liquid SO_2, an operation which is now carried out on a very large scale at the refineries at Skewen, is of interest.

It is clear, therefore, that the need for systematic research into the character of petroleum products is urgent, and it is gratifying to note that the Anglo-Persian Oil Company has established a research laboratory at Sunbury-on-Thames, in which the important principles underlying the industry have been and will be studied.

Dyestuffs and Intermediates.

Prior to the war Germany manufactured three-fourths of the dyestuffs required for the world's markets. Of the remaining one-fourth, one-half was made from German intermediates and was, therefore, dependent on Germany. Switzerland, although without a domestic source of raw materials, ranked second with about 7 per cent. of the world's production. Great Britain produced about one-tenth of her requirements, and France produced in French-owned and operated plants from 10 to 15 per cent. of her consumption. In order to meet the patent requirements of France and Great Britain, German manufacturers operated plants in those countries where the final assembling operations were completed. The small dye industry of the United States was almost entirely dependent upon German intermediates. At the present time Great Britain produces 80 per cent. of the dyestuffs required for our own use, and we are, therefore, in a position to review the conditions which have led to this remarkable change and to consider the procedure necessary to strengthen it. It cannot be said that any fundamental advance in the chemistry of the dyestuffs has been made since Bohn discovered indanthrene in 1901, although great advances have been made since then in the preparation of new colours belonging to this and other known series. Consequently the

research work necessary in order to establish our position as a dye-making country has been mainly along known lines, involving the extension of reactions which had already been established rather than the discovery of new ones. Nevertheless it is no inconsiderable achievement for our research chemists to have established a position such as that indicated above in so short a space of time, for many of the preparations, the details of which could only be found in the patent literature, had to be worked out *de novo* and the correct conditions found for their adaptation to the technical scale. It is probably along the lines of decreased cost of production that research work in the immediate future will be mostly engaged, and especially is this the case with the intermediate products from which the dyestuffs are derived. Moreover, the intermediate products are of the greatest importance for other industries, for example, the Fine Chemical Industry, the Perfumery, and the Explosives Industries, and any improvement in the processes for their manufacture or the production of new compounds having enhanced value from the commercial point of view is of the greatest importance to all these industries alike. The parent substances of the intermediate products are the hydrocarbons of coal-tar or the coke-oven by-products. The operations required to convert these hydrocarbons into the finished intermediates often involve many stages, any one of which depends for its cost on the purity and yield of the product. When large quantities are involved a difference of 1 per cent. in the yield may lead to a considerable difference in the cost of production, and it is obvious that reactions which yield their products in a state of purity sufficient for the market or further stage production without subsequent treatment make for reduced cost in production. There is thus a wide field for research into the improvement of technical methods which may well occupy the attention of our dyestuffs chemists for some time to come. On the other hand, the question of fundamental research into new processes, both for the preparation of new intermediates and new dyestuffs, must not be lost sight of. The intermediate determines the character of the dyestuff, and it is always possible that a new intermediate may be discovered which will yield a dyestuff with just that difference of shade as to catch the public fancy, and which will lead to the replacement of the older dyestuff on the market. The sulphonic acids of the naphthol, naphthylamines and amino-naphthols are cases in point. These substances are used extensively for the preparation of azo dyes. There are a great number of these compounds theoretically possible, but only a few have found technical application, owing mainly to the high cost of producing the others. The high cost is nearly always caused by poverty of yield, an objection which may be at any time removed by the discovery of an improved process. The same argument holds good for the dyestuffs themselves. It is futile to say that the vast field of organic chemistry has been thoroughly explored f r the production of new types. At any moment one or other of the men or women engaged in fundamental research may repeat Bohn's discovery of 1901, and obtain a new compound which will be the forerunner of a new series of dyestuffs. It is perhaps too much to ask an industry which is struggling to hold its own to expend large sums on the prosecution of abstract research, most of which will be of no use to it,

but it is not too much to expect that the industry will take every means to foster and encourage abstract research in our university institutions, and even to give some hint as to the direction in which its experience leads it to think that advances may be made. There is at present no organisation which can bring the manufacturers of dyestuffs and intermediates into touch with the work being carried on in our university laboratories, and it is possible that if at the present time a valuable discovery were to be made it would be unrecognised as such, and, following the usual course of academic research, would be published and thus lost to the country. What is required is a lead from manufacturers which will indicate the matters which they regard of importance, but which they do not consider as likely to yield results sufficiently quickly to justify them in employing their own research staff for investigating them. This aspect is of all the more importance at the present time, when organic chemistry is entering on a new phase which will undoubtedly revolutionise many of the existing processes of manufacture. It is now recognised that the presence of a small quantity of a catalyst may either alter the course of a reaction or may lead it to proceed to completion where otherwise a totally inadequate yield would be obtained. The catalyst may either be added or the containing walls of the reaction vessel may act in this capacity. The well-known example of the oxidation of naphthalene to phthalic anhydride by vanadium pentoxide is an example of this, but similar cases are continually recurring, and it has only recently been found that the classical method for preparing ketones by the distillation of the calcium salt of the appropriate acid can be utilised in the most unexpected directions if the thorium salt instead of the calcium salt is employed. It is perhaps appropriate to conclude this section by the following quotation from the United States Tariff Commission Report, No. 32 :—

'The acute shortage of dyes arising in the various dye-consuming markets, due to the disappearance of German dyes shortly after the beginning of the war, was soon followed by prices of unprecedented levels, while certain dyes were not to be had at any price. This dye famine threatened the activities of the vast textile industries, as well as other industries dependent upon dyes for their operation. The manufacture of dyes was soon entered upon in the United States, Great Britain, France and Italy, and each of these countries has developed a dye industry capable of supplying from 80 to 90 per cent. of its requirements and has, in addition, exported significant quantities of dyes since the war. As a result of this remarkable period of expansion and development the world's present capacity to produce dyes is nearly double that of the pre-war period. This existing capacity to produce over and above normal requirements is resulting in an era of severe competition in the world's markets which may eliminate many of the plants now in operation. The German industry has certain advantages over the industries of the new producing countries, including cumulative experience, unified organisation for buying and selling, and lower manufacturing costs. The high post-war price levels of dyes exported from Germany would appear to indicate a strong probability of price reductions during the next few years. The commercial warfare which is likely to follow may involve the utilisation of

such methods as full-line forcing and dumping, such as was practised by the German chemical industry prior to the war. The retention of a tariff and other protective measures by the new producing countries will doubtless lead the German industry to form affiliations to establish branch plants in those countries. The war made clear the relationship of the coal-tar dye industry to the production of munitions, war gases, medicinals, and other essential products, and demonstrated the desirability of home dye production as a means to prevent shortage in times of war. This will probably result in an effort by the large industrial nations to retain dye industries of sufficient size to meet peace requirements and to provide for war emergencies. Reduced production costs and constructive research will be vital factors in the maintenance of their competitive place in the world's trade.'

This seems to sum up the situation with which we are at present faced.

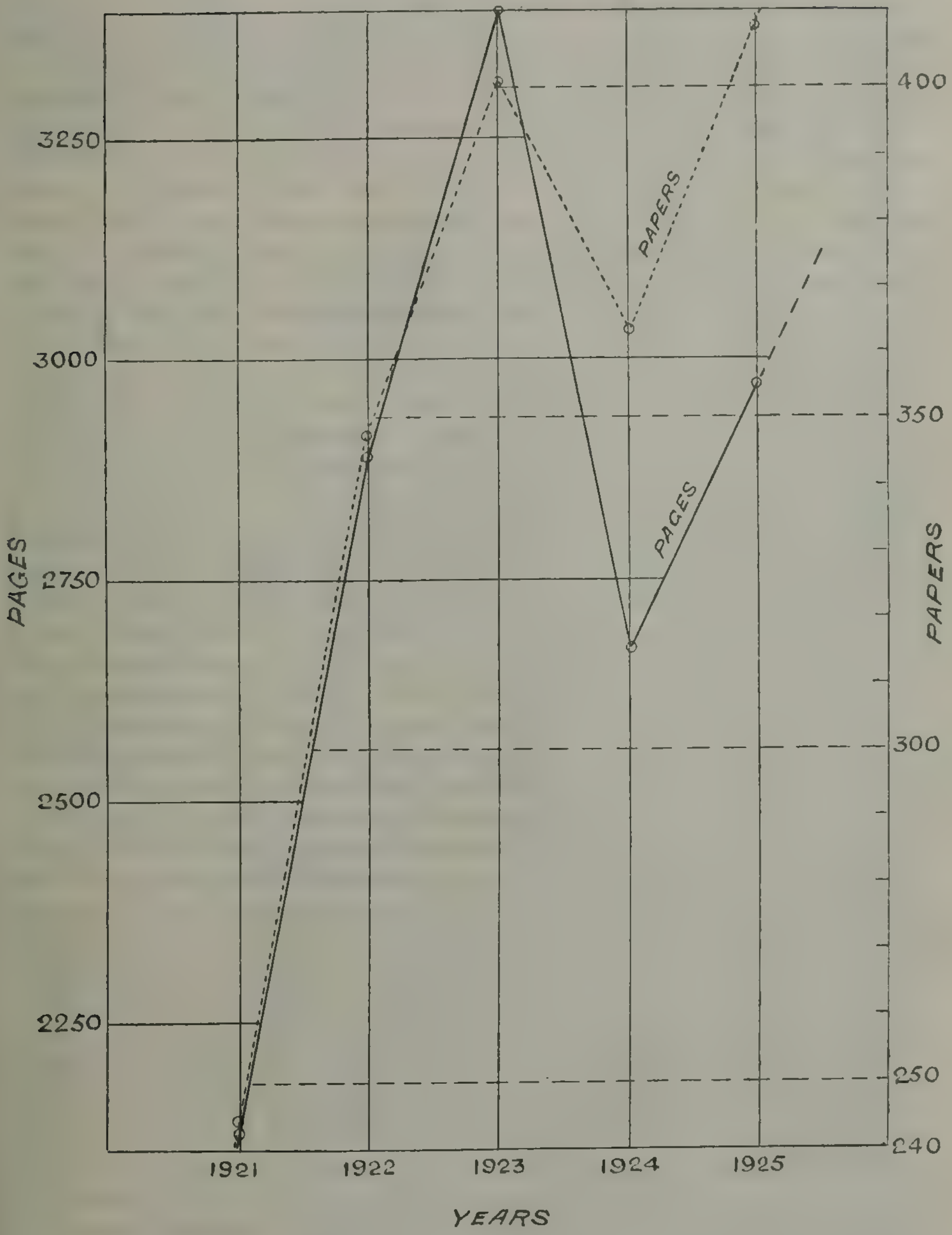
Publications.

Our chemical publications grow apace—already they have outstripped in number and size those produced prior to the war. If one may take the Journal of the Chemical Society as representing a standard example, it may be noted that the number of pages published in 1914 was 2,909, whilst in 1923 the number was 3,441. This was reduced in 1924 to 2,698 pages, but rose again in 1925 to 2,986 pages. The drop in 1923-1924 was not, however, due to lack of material but to the exercise of necessary economy, because the costs of printing have increased by 70 per cent. since the war, and the funds of the Society could not carry the increased expenditure. Until new sources of income could be created economy had to take the form of asking authors to cut down their papers to the greatest possible extent, and this had the effect of checking the advance for that year. Nevertheless during 1925, although authors continued to co-operate and still expressed their views and results in as small a space as possible, the steady rise in the amount of research work carried out in the country led to an increase in that year, showing that the new matter was due to new research, and was not the outcome of any remissness on the part of the Publications Committee. This fact is well brought out by the following graph, which shows the incidence of the number of published papers and the number of pages published.

The increase is still continuing, and is a welcome sign of the healthy condition in which research in chemistry stands at the present time. Still it means a Journal of well over 3,000 pages for 1926, and represents a condition of affairs which is shared by many other scientific societies.

There were many national scientific shortcomings revealed by the war, but it is probable that those in the chemical sciences loomed largest because they were the ones which had to be rectified by makeshift arrangements at the time, and although our national aptitude rose to the occasion, and we blundered through in our usual manner, yet when time for thought occurred the contrast between our state of unpreparedness and the complete scientific equipment of our enemies was very marked, and gave cause for earnest consideration. The result has been a great increase in the numbers entering our chemical research schools and the consequent output of an increased amount of new knowledge, all of which has to be

RECORD OF PAGES AND PAPERS
PUBLISHED BY
THE CHEMICAL SOCIETY. (1921–1925).



recorded. The burden of publication has fallen, therefore, heavily on the societies dealing with chemistry, and more particularly on the Chemical Society, which is the chief means by which, through its Journal, new knowledge is published to the world.

The remedy is not obvious. The societies cannot increase their subscriptions without inviting loss of membership. Neither does it seem that much is to be gained by amalgamation, because each society deals with some branch of chemistry, and there is little or no overlapping or duplication. Amalgamation of the societies would not, therefore, decrease the costs of publication nor materially diminish the subscriptions necessary to meet these costs.

You cannot curtail papers beyond the point which enables the work described to be repeated, otherwise publication is valueless. You cannot say within wide limits that new knowledge is not worth recording, or that views expressed are best suppressed. The criticism has been raised that the modern tendency to issue short communications at frequent intervals leads to premature publication, and that much that is published has to be corrected in later papers, and it cannot be denied that recent experience has shown this criticism to be partly true. But it has been the custom of societies to accept short papers with more avidity than long ones, and in consequence authors have come to realise that the short communication stands more chance of acceptance than longer ones. The policy is in a sense wrong, because a series of short papers on the same subject necessarily leads to redundancy and frequently to a revision of the views expressed in earlier parts as the work progresses. The trouble seems to lie in the custom which requires an introduction to the series, the aim of which is to give the reader who has no interest in the experimental details a readable account of the scope of the work. If this ' introduction ' were abolished and a ' summary and conclusions ' placed at the end of the paper or series of papers, it would no doubt crab the literary style of the author and detract from the value of the communication as bed-side reading matter, but it would most certainly shorten the paper and would no doubt enhance its value from the scientific standpoint.

When it is remembered that there are some 23,000 scientific periodicals published throughout the world the mind stands appalled at the prospect that will confront civilisation even in so short a time as 100 years hence, unless some general method of curtailment is agreed on. The space occupied by our ever-increasing libraries must cause alarm to those who contemplate the possibilities of the future. The agreement between the various societies dealing with chemistry to form a joint library at Burlington House means at the present time an increase of something like 800 volumes yearly—an increase which will augment as time goes on. In the not far distant future the library will occupy the whole of the space available in the society's apartments, and the same problem has to be faced by every other scientific society. Indeed, civilisation seems to be confronted with two ever-growing problems—the increases in its cemeteries and in its libraries. The former, no doubt, will be solved by cremation. Is it too much to hope that a judicious exercise of this method may also be applied to our libraries ?

PROGRESS IN THE STUDY OF THE LOWER CARBONIFEROUS (AVONIAN) ROCKS OF ENGLAND AND WALES.

ADDRESS BY

PROF. S. H. REYNOLDS, M.A., Sc.D.,

PRESIDENT OF THE SECTION.

It is now about ten years since our science suffered an irreparable loss in the premature death of that brilliant worker on the Carboniferous rocks, Arthur Vaughan. Only twenty years have passed since the publication of his classical paper on the 'Palæontological Sequence in the Carboniferous Limestone of the Bristol Area,' and when we think of what he accomplished during the ten years in which he devoted his scanty leisure to the study of the Lower Carboniferous rocks we may well wonder what he would have achieved by now were he still with us.

Vaughan's chief work was done at Bristol, but the last few years of his life were spent at Oxford. I hope it is not inappropriate that one who hails from Bristol and was associated with Vaughan in some of his work should choose the Lower Carboniferous rocks for an address at Oxford.

This subject was not chosen without careful consideration, but it may be doubted whether I am well advised in attempting it. In the first place I am fully aware of the others who are better qualified to deal with it than I am myself. In the second place there is so much work in progress, particularly in the Midlands and in the North, and there is still such difference of opinion on many important problems, that there is much to be said for postponing any such attempt as I am now making. Part of the ground, too, has been covered by the report of a committee of this Association presented at the last Meeting (Southampton), while Prof. Kendall's chapter in the 'Handbuch der regionalen Geologie' renders any general survey of the succession unnecessary. I have therefore chosen for consideration a number of subjects unrelated except in so far as they are concerned with the study of the Avonian rocks.

All the workers to whom I have applied for information have most kindly and willingly helped me, and I should like to acknowledge my special indebtedness to Mr. R. G. S. Hudson, Dr. Stanley Smith, and particularly to Mr. Ernest Dixon. Thanks to the help I have received I am hopeful that, although this address contains little that is novel, it may prove a useful summary.

I have decided to restrict my subject to England and Wales.

Note.—I wish to convey my sincere thanks to the following for help and information: Mr. W. S. Bisat, Mr. R. G. Carruthers, Dr. R. Crookall, Prof. E. J. Garwood, Mr. T. Neville George, Dr. E. Greenly, Mr. J. W. Jackson, Mr. W. W. Jervis, Mr. Cosmo Johns, Dr. D. Parkinson, Mr. H. C. Sargent, Dr. T. Franklin Sibly, and Dr. A. E. Trueman.

It has long proved convenient to divide England and Wales into provinces, each characterised by its own special features of deposition during Lower Carboniferous times. The following provinces have been generally recognised:—

1. *Devonshire*, including parts of North Cornwall.
2. *South-western Province*, including the Bristol district, the Forest of Dean, South Wales, and the Clee Hills.
3. *Midland Province*, including Anglesey and North Wales, the Wrekin, and the midland area of Derbyshire, Staffordshire and Leicestershire.
4. *Yorkshire Province*, including the Craven and Dale country and the Clitheroe and Colne region of Lancashire.
5. *North-western Province*, including parts of North-west Yorkshire, Westmorland, North Lancashire and Cumberland.
6. *Northern Province*, including Durham and Northumberland.

Subdivisions of the Avonian Rocks in the South-western Province.

Vaughan's subdivisions have been adopted by all workers on the Carboniferous Limestone in the central and south of England and by all recent workers in Wales and Ireland.

Certain modifications of his original classification have been introduced from time to time and will be alluded to in stratigraphical order.

1. In his original 'Bristol' paper (1905) he called the lowest Carboniferous rocks transitional from the Old Red Sandstone *Modiola* zone (M), pointing out, however, in a footnote that the *Modiola* zone had better be regarded as a shallow-water phase of the *Cleistopora* zone (K). Soon he definitely adopted this arrangement, so that the *Modiola* zone became Km. Later on[1] Vaughan dropped the term Km, including these deposits in K_1. The term Km is, however, used in the table of classification appended to the Belgian[2] paper, and is used in a phasal sense in the Tenby memoir.

2. Although, as Vaughan explains, the fact that *Caninia* has two maxima, one in the Tournaisian and one in the Viséan, is a reason why he did not adopt it as an index fossil, he still makes use of the term *Caninia* zone. In his original paper he uses it as including the *Syringothyris* zone (C), which he did not then subdivide, and the lower part of the *Seminula* zone (S_1). In the Winnipeg report the expression '*Syringothyris* and *Caninia* zone C' is used. In the Gower paper (1911) the term '*Syringothyris* zone' is still used, but in the Burrington paper (1911) it is dropped in Vaughan's portion of the paper, the *Caninia* zone (Middle Avonian) being taken to include γ and C_1. Dixey and Sibly[3] also drop the term *Syringothyris* zone.

[1] *Q.J.G.S.*, vol. lxvii. (1911), p. 363.
[2] *Ibid.*, vol. lxxi. (1915).
[3] *Ibid.*, vol. lxxiii. (1918).

The symbol γ was originally applied to rocks at the level of co-occurrence of *Zaphrentis* and *Caninia*. In the table of succession of the Bristol paper these are grouped with Z, but in that of the Gower paper with C. In the Burrington paper Vaughan re-defined horizon γ as beds with abundant *Caninia patula* and without *C. cylindrica* (Scouler) Salée, and extended it so as to include the major portion of C_1 (styled $C_1\gamma$ in the illustrations). As Dixon[4] remarks, the value of γ as a means of comparing distant developments has been much enhanced, *C. patula* having a wide distribution but apparently limited range.

3. The most important change since the publication of Vaughan's original paper has been in the dividing line between Tournaisian and Viséan. Vaughan originally drew the line at the top of the *Syringothyris* zone. Dixon,[5] however, showed by the study of the Gower section and others in South Wales that a slight discordance, becoming more pronounced along the outcrop north of the coalfield, occurs in places between C_1 and C_2, and that it was at the top of C_1 that emergence in the south-western province temporarily interrupted subsidence, to give way in turn to renewed subsidence. He further showed that over a large area, particularly in Pembrokeshire, C_2 and S_1 are not sharply separable, either as regards lithology or fauna. Consequently he drew the line between Tournaisian and Viséan at the top of C_1, and in this he has generally been followed by workers in the South-western Province. Vaughan, however, on fossil evidence preferred to draw the line somewhat above the break, *i.e.* in the middle of C_2, and this is also the level adopted by Delépine in Belgium.

4. In the Bristol paper horizon δ, that of overlap between the C and S zones, is shown in the table of succession, but its limits and faunal characters are not defined, as was done in the case of horizons β and γ.

The term horizon δ is practically dropped in all the earlier papers on the British Carboniferous Limestone. In his later paper (Correlation of Avonian and Dinantian) Vaughan revives the term in an emended and extended sense so as to include upper C_2 and S_1 of the original classification, *i.e.* from the maximum of *Cyathophyllum* ϕ to the incoming of *Cyrtina carbonaria*. Vaughan[6] gives full details as to the faunal characters of this level, and indicates the corresponding level in a number of sections throughout the British Isles and in Belgium.

Vaughan introduced the term Avonian, which is nearly equivalent to the Belgian Dinantian, to replace the somewhat cumbersome designation Carboniferous Limestone Series. He also habitually used the terms Tournaisian and Viséan for the lower and upper Avonian respectively, though the use of the terms was not quite identical with their use in Belgium. He suggested the terms Clevedonian and Kidwellian as alternatives, and if it be essential that terms be used strictly in the sense in which they were originally employed, these should replace Tournaisian and Viséan. The terms Tournaisian and Viséan are now so thoroughly established with us that it would probably be impossible, even if desirable, to displace them. British geologists will doubtless continue to use them

[4] *Pembroke and Tenby Memoir*, p. 65.
[5] *Q.J.G.S.*, vol. lxvii. (1911), p. 542.
[6] *Ibid.*, vol. lxxi. (1915), p. 17.

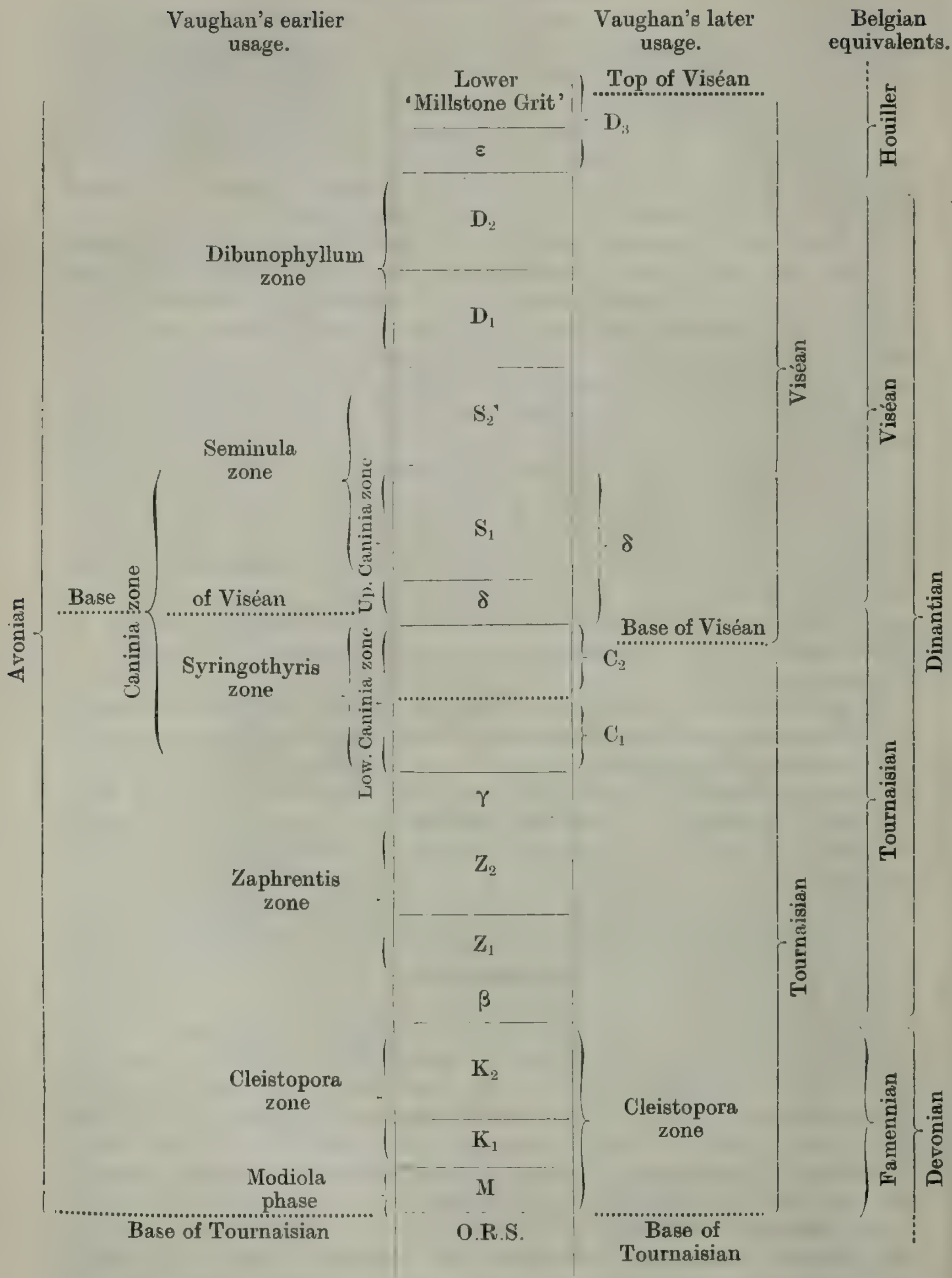


Fig. 1.

Table showing the Subdivisions of the Avonian Rocks in the South-western Province and their Equivalents in Belgium.

in the same sense as heretofore, not binding themselves by adherence to the Continental usage.

Note.—The chief differences between the British and Belgian use of the terms Tournaisian and Viséan, and between Avonian and Dinantian, are :

1. In Belgium the K beds are excluded from the Dinantian and grouped with the Famennian.

2. The line between Tournaisian and Viséan is drawn in Belgium at about the middle instead of at the base of C_2.

3. The top of the Dinantian is drawn at the base of the Yoredale equivalent, that of the Avonian at the top.

Variability and Persistence.

In my remarks on this subject the Northern Province is not taken into account.

The several horizons of the Avonian differ much as regards variability and persistence.

The *Cleistopora* beds are both the lowest and most constant horizon. Throughout the Bristol area, South Wales and the Forest of Dean, where alone they are present, they show remarkable constancy not only in faunal and lithological character but in thickness. Metasomatic changes such as dolomitisation and silicification have affected them very little, and while in parts of the South Wales coalfield all the other horizons are concealed by overstep of the Millstone Grit, the *Cleistopora* beds are never reached.

The *Zaphrentis* beds, which are also comparatively little developed in the region under consideration outside the South-west Province, are relatively constant in lithological character. They are predominantly crinoidal limestones of the 'petit granit' type, but may sometimes be highly dolomitised or silicified. They are concealed by overstep in parts of the South Wales coalfield.

The *Syringothyris* beds, the oldest strata commonly seen in the North-west Province, show much variability. In the south they contain much dolomite, and the whole or part may be cut out by non-sequence or concealed by overstep as in the South Wales coalfield.

The *Seminula* beds, the oldest strata occurring in the Midlands or North Wales, are also a variable series. In the Bristol district they are on the whole more frequently exposed than any other horizon.

The limestones of the lower *Dibunophyllum* zone (D_1) are the most constant limestones in faunal and lithological characters of the whole succession. Throughout the whole of the Bristol district, North and South Wales, the Midlands, Yorkshire and the North-west Province, wherever limestones of this level occur, they are of the same general type, save in certain districts where the Knoll facies is found. The Avonian rocks of later date than the D_1 beds are much more variable.

Relations of the Carboniferous to the underlying Rocks.

Wherever the Carboniferous and Devonian (O.R.S.) rocks are seen in relation to one another the succession is conformable save in Carmarthenshire, at Kidwelly and Llandebie, where, as Mr. T. N. George informs me,

there is evidence of a slight discordance. Except in North Devon, where the Carboniferous rocks succeed marine Devonians, there is a gradual passage from rocks of the Old Red Sandstone facies deposited under continental conditions to rocks of definitely Carboniferous character deposited under marine conditions, and the horizon at which the dividing line between the two formations is drawn is often, as in the Avon section, merely a matter of convenience. Thus in the Avon section the line is drawn above the highest band in which fish remains were found. In the Tenby district Dixon[7] states that the conformable passage is sometimes gradual, sometimes with abrupt change of conditions. In the Forest of Dean[8] there is no appreciable development of a transition series.

In North Devon the lower part of the Pilton beds—a variable series of shaly, gritty and calcareous strata—contains a fauna of predominantly Devonian type, while the upper Pilton, though containing some Devonian species, is more related to the Carboniferous. No full description of the Pilton faunas is yet available, but Vaughan[9] correlated the *Productella productoides* beds with Km, and stated that in the uppermost Pilton beds the fauna is essentially a β fauna with a few persistent Devonian forms. This would be in accord with Evans'[10] correlation of the Baggy and Lower Pilton beds of North Devon with the Upper Famennian.

The Midland counties of England were mainly land areas in lower Avonian times, and the upper Avonian rocks rest with strong unconformity on Lower Palæozoic or Precambrian rocks.

Unconformities and Breaks in the Succession.

A. *In the Culm of Devon and Somerset.*

While the Upper Pilton beds of North Devon apparently represent the K and β beds of the S.W. Province, no representatives of any later horizon have been recognised till one reaches D_3, to which level the lowest zones of the Culm are assigned.

B. *In the South-western Province.*

(1) *Mid-Avonian breaks and unconformities.*

It is well established that there is evidence of disturbed conditions in mid-Avonian times in the S.W. Province, increasing in intensity as one passes N. and N.W. from the Bristol area. Thus, while in the Mendip region the C beds are to a large extent represented by 'standard' limestone, in the Avon section and those of Gower and along the S.E. margin of the South Wales coalfield the place of standard limestone is taken by shallow-water oolites, shales and dolomites. Farther west, in Carmarthen, much, if not all, of the C beds and of horizon γ is missing, while in most localities the Z beds are also absent, so that at Fan and other places near Kidwelly, and for many miles along the outcrop to the north of the South Wales coalfield, the S_2 beds rest directly on the K beds. Along the northern crop of the Pembroke coalfield west of Carmarthen Bay the same state of affairs

[7] *Pembroke and Tenby Memoir*, p. 67.
[8] Sibly, *Geol. Mag.*, Dec. v., vol. ix. (1912), p. 418.
[9] *Q.J.G.S.*, vol. lxvii. (1911), p. 385.
[10] *Geol. Mag.*, Dec. vi., vol. vi. (1919), p. 548.

is found, the S_2 beds resting directly on the K beds. At Pendine they have a conglomeratic base, but no such rock is known E. of Carmarthen Bay. On the south crop of the Pembroke coalfield, at West Williamstown, there is only a slight break between C_1 and C_2, while at Tenby the sequence is complete, though the C beds are of shallow-water type. In the southernmost part of Pembrokeshire not only is the sequence complete, but the C beds are represented by 'standard' limestones.

(2) *Post-Avonian Unconformities.*

Throughout South Wales, in the Forest of Dean and in the Clee Hills district, there were upheaval and erosion prior to the deposition of the Upper Carboniferous. At the Titterstone Clee[11] and in the Forest of Dean the Coal Measures rest unconformably on various levels of the Avonian. Along both the south-eastern and northern crops of the South Wales coalfield the Millstone Grit shows remarkable over-stepping relations to the Avonian rocks. These are described in the section dealing with the Millstone Grit. In the Clevedon and Clapton district of North Somerset no representatives of any Avonian horizons higher in the series than the *Caninia*-dolomite (C_2) are met with. In the Clapton district the Coal Measures rest directly on *Zaphrentis* beds. In the Clevedon district the relation of the Coal Measures to the Avonian rock is sometimes faulted, sometimes indeterminable.

It is very rare in the Bristol district and North Somerset to get sections showing the relations of the Millstone Grit to either the overlying or underlying strata. The best section from the Carboniferous Limestone to Millstone Grit is probably that at Wick Rocks, while the best section from the Millstone Grit to the Coal Measures is that described by Dr. H. Bolton[12] from Ashton Vale.

In neither of these sections has any break in the sequence been observed, though, as is pointed out more fully in the sequel, the occurrence of Yorkian plants in the upper part of the Millstone Grit shows that if, as is generally believed, the lower part is Avonian, the upper is much later, so that a considerable gap occurs in the sequence. In the Radstock area a second big gap occurs, namely between the Yorkian (upper Millstone Grit) and the Coal Measures, which are represented only by the uppermost group, the Radstockian.[13]

C. *In the Midlands and North of England.*

Mr. J. W. Jackson's work shows the existence of an important unconformity above the D_3 beds of North Derbyshire. The Edale shales, which lie between these beds and the Kinderscout grit, were formerly regarded as Avonian, and often grouped with the Yoredalian. Mr. Jackson confirms Hind's[14] conclusion that they are of later date, and shows that they contain goniatites of Bisat's zones R_1, H and Upper and Middle E (*bisulcatum* beds). There is a break below the *bisulcatum* beds, the

[11] Dixon, *Rep. Brit. Ass.*, Sheffield (1910), p. 611, and *Geol. Mag.*, 1910, p. 458.
[12] *Q.J.G.S.*, vol. lxiii. (1907), pp. 445-69.
[13] The above statements are based on information supplied by Dr. R. Crookall and on his papers in the *Geol. Mag.*, vol. lxii., 1925.
[14] *Geol. Mag.*, Dec. iv., vol. iv. (1897), p. 209.

pseudobilinque beds and certain underlying shales ('Pendleside shales') being absent.

Sibly[15] describes a case near Youlgreave where the 'Pendleside shales' with *Posidoniella lævis* rest on D_2, the *Cyathaxonia* beds, D_3, being absent; Wedd[16] a similar case near Bridgetown, Derbyshire. Mr. Hudson informs me that in the Knoll region of Cracow the upper Bowland shale rests unconformably on the Knoll limestones, which were subject to uplift and denudation prior to the deposition of the lower E beds.

The great post-Avonian unconformity at the base of the Millstone Grit is described more fully in the sequel.

Note.—The nomenclature of the rocks of the Pendle Hill area is very confusing to those unfamiliar with the district. The Pendleside group of Hind and Howe (1897) originally included all the strata between the Mountain Limestone and Millstone Grit, and was considered to be all of Upper Carboniferous age. Subsequently Hind relegated the lower part of his 'Pendleside series' (the 'shales with limestone' of the Survey and the Worston shale of Parkinson) to the D beds, leaving the Pendleside limestone and overlying shales, the Bowland shale of Phillips, in his 'Pendleside group.' He also included in it the shales overlying the Pendle top grit, which later work has shown to be Lancastrian. It is clear from the above account that, although the terms 'Pendleside' and 'Pendleside group' are frequently employed as roughly equivalent to Phillips' Bowland shale, they lack definiteness and there is little to justify their retention. Mr. Bisat[17] and Dr. Parkinson[18] clearly show that the terms, as indicating a time division, had better be dropped.

The grits of the Pendleside section are also confusing, and in hopes of making things clearer I have carried on the section in Table II. up to the Kinderscout grit from information supplied by Dr. Parkinson.

Piping or Pot-holing under Subaerial Conditions on Levels of Unconformity.

Several interesting examples have been described :—

(*a*) Dixon describes[19] very remarkable cases from Ifton, Monmouth, where the S beds below the Millstone Grit are worn into steep-sided channels and cavities, some of unknown depth filled with sandstone and shale.

(*b*) In the Forest of Dean Sibly describes[20] piping of the Carboniferous Limestone by Coal Measure sandstone at Ruardean.

(*c*) Dixon alludes[21] to piping at Llanmarch Dingle, near Brynmawr, in the north-eastern portion of the South Wales coalfield. Here grit fills holes in the Carboniferous Limestone.

15 *Q.J.G.S.*, vol. lxiv. (1908), p. 63.
16 *N. Derby Memoir*, p. 35.
17 *Proc. Yorks Geol. Soc.*, vol. xx., pt. 1 (1923-4), p. 45.
18 *Q.J.G.S.*, vol. lxxxii. (1926), p. 223.
19 *Geol. Mag.*, vol. lviii. (1921), p. 157.
20 *Ibid.*, Dec. vi., vol. v. (1918), p. 26.
21 *Q.J.G.S.*, vol. lxxiii. (1917), pp. 161-2.

(*d*) Piping occurs in Z beds at Pendine[22] below the conglomeratic base of the S beds, and at Haroldston St. Issell[23] Millstone Grit pipes into limestone of a low S horizon. At West Williamstown[24] the case is somewhat different, as here the material forming pipes in the *Caninia*-oolite (C_1) is C_2 mudstone, and consequently does not imply any considerable break. It was found, however, that the upper part of the *Caninia*-oolite is missing, and the inference was drawn that the case at West Williamstown is analogous to the others, the emergence, though brief, being sufficient to bring the limestone within reach of subaerial agencies.

(*e*) Greenly describes[25] cases in Anglesey where at several levels in D_2 beds of sandstone pipe into the limestone.

(*f*) In the West Cumberland area Edmonds[26] and Dixon[27] describe contemporaneous pot-holes recurring at several horizons in the Fourth limestone (D_1 to D_3). They are mainly cylindrical, with an average diameter of 2 feet and depth of 4-6 feet. They widen out rapidly at the top and are filled with mudstone, sandstone or rubbly limestone. They point to repeated intervals during which subsidence and deposition of limestone were interrupted by elevation above sea-level and contemporaneous erosion.

(*g*) Near Ingleton pot-holes in D_1 limestone have been recognised by Dixon.[28]

(*h*) The pits in the pitted D_1 limestone of Gower[29] are also of the character of contemporaneous pot-holing.

Phasal Equivalents of the Avonian.

In his most suggestive report presented at the Winnipeg Meeting of the British Association in 1909 Vaughan recognised three phasal equivalents, and introduced, though without defining, the following terms to express them :—

1. Standard fauna.
2. *Zaphrentid* and *Cyathaxonid* phase.
3. *Modiola* and *Posidonomya* phase and other shallow-water deposits.

He regarded the ' standard fauna ' as indicating the greatest depth of water, and the *Modiola* and *Posidonomya* phase the least.

1. *Standard phase.*—This type of deposit, which is mainly calcareous in character, is seen in most of Z, γ, S_2 and D_1 in the Avon section and in the Mendips also in C_2 and C_1. In the North-west Province and in the Midlands D_1 and D_2 are standard phase and in N.W. Yorkshire and Westmorland S and the whole of D_1 and D_2.

2. *Zaphrentid and Cyathaxonid phase or fauna.*—Dixon gives a clear statement of the sense in which he uses this expression. He describes the

[22] *Haverfordwest Memoir*, p. 142.
[23] *Ibid.*, p. 151.
[24] *Ibid.*, p. 142.
[25] *Geol. Mag.*, Dec. iv., vol. vii. (1900), pp. 20-24, and *Anglesey Memoir*, pp. 612-16.
[26] *Ibid.*, vol. lix. (1922), pp. 120-1.
[27] *Summary of Progress for* 1921, pp. 53-4.
[28] *Q.J.G.S.*, vol. lxxx. (1924), p. 215.
[29] Figured *Q.J.G.S.*, vol. lxvii. (1911), pl. lxxxviii., fig. 1.

rocks as thinly and evenly bedded dark argillaceous limestones interbedded with shales and including much chert, which is typically black. Fossils are generally abundant, and include crinoids, simple corals (*Zaphrentis*, *Cyathaxonia*, *Caninia*), bryozoa, such brachiopods as frilled athyrids, spinose productids, *Syringothyris* and *Spiriferina*, *Leptæna analoga*, *Rhipidomella michelini*, *Schizophoria resupinata*. Small trilobites are less abundant.

Rocks of this type occur in the K and Z beds of various sections in the South-west Province, and are typically represented in the D_3 (*Cyathaxonia* beds) of Oystermouth Gower, the Craven lowlands, and Derbyshire. They probably indicate muddy conditions, depth being immaterial. Dixon[30] points out that the study of the fauna of Zaphrentid phases has upset former ideas as to the zonal importance of certain forms. Thus an upper Avonian Zaphrentid phase such as that of S_1 at Bosherton, Pembroke, suggests at first sight a level in Z or γ.

The thin-bedded dark limestones of upper D_2 in Derbyshire and the Cement Stone development of the Northern Province seem to be intermediate in character between standard limestones and Zaphrentid-phase beds.

3. The third phase is styled in Vaughan's table '*Modiola* and *Posidonomya* phases and other shallow-water deposits.' The deposits included under this head, which are very varied and widespread, are divisible into two main sections :—

(*a*) *The lamellibranch-goniatite or Culm phase.*

(*b*) *The lagoon-phase deposits* (Dixon), including

(1) *Modiola phase*=calcareous lagoon-phase.

(2) *Radiolarian phase*=cherty lagoon-phase.

This large and varied series of deposits seems to me to overweight the third phase, and I think that it would be a distinct convenience to separate the lagoon-phase deposits as a fourth phase.

(*a*) The *lamellibranch-goniatite or Culm phase* is very widespread and important in the North of England, and is represented also by the Culm of North Devon.

The rocks consist of thin-bedded black shales, often papery, with thin limestones prevalently of the calcite-mudstone type, and more rarely radiolarian cherts. Sandstone bands may be present, but are not essential. The fauna is somewhat monotonous, and forms with thin shells prevail.

(*b*) *Lagoon-phase Deposits.*

The term was introduced by Dixon[31] to connote a group of rocks deposited in wide but shallow coastal areas more or less isolated from the deeper parts of the sea. In such 'lagoons' rocks of a peculiar type and containing a peculiar fauna and flora were deposited. Dixon distinguishes two types of lagoon phase :—

(1) *Modiola phase*=calcareous lagoon-phase.

[30] *Pembroke and Tenby Memoir*, p. 72.
[31] *Q.J.G.S.*, vol. lxvii. (1911), p. 511.

The rocks grouped here include china stones and other calcite mudstones, dolomite mudstone, oolite, pisolite, algal limestones, ferruginous bryozoal and crinoidal limestone of the type of the well-known Bryozoa bed (hor. α) of the South-west Province.

The characteristic fossils of the *Modiola* phase are small lamellibranchs, ostracods, spirorbid annelids, foraminifera and calcareous algæ. The brachiopod *Seminula* is also characteristic.

Bands of standard limestone with the normal fauna are intercalated at certain localities and horizons, probably indicating invasion of the lagoon area by the open sea.

(2) *Radiolarian phase*=cherty lagoon-phase.

These rocks show far less lithological variability than the calcareous lagoon-phase rocks, and are far less abundant. They consist of chert bands alternating with shales.

Dixon shows that radiolarian cherts are not, as was claimed by Hinde, necessarily deep-sea deposits, and that they may be interbedded with shales which are clearly of shallow-water origin. The finely laminated and current-bedded character of many cherts is inconsistent with a deep-water origin. The evidence for the existence of these radiolarian lagoon phases was obtained by Dixon in Gower, and he points out that, though absent in the Bristol area, such phases occur throughout the whole area south of the Pembroke coalfield. He claims that the radiolarian cherts of the Culm of North Devon were accumulated under lagoon-phase conditions. Dixon in the Gower paper recognises four *Modiola* phases, three of which, those of Km, C_2, and top of S_2, are very widely traceable throughout the South-west Province. They are essentially similar in the Avon, Sodbury and Tytherington sections, the S_2 development being particularly prominent at Sodbury. In the Burrington section *Modiola* phases are not conspicuous, the Km beds being ill-exposed, C_2 being mainly standard limestones, and the S_2 development relatively thin. The fourth Gower lagoon phase is at the base of P.

In the eastern part of the South Wales coalfield *Modiola*-phase conditions start earlier than in the Gloucestershire sections, and a lower *Modiola* phase (C_1-C_2), 250 ft. thick, is separated by 100 ft. of dolomite from an upper *Modiola* phase (S_1) at Cefn On, to the north of Cardiff.

The rocks of the isolated mass of Cannington Park[32] (S_1) near Taunton appear to be mainly of *Modiola*-phase type.

In the Forest of Dean the Km *Modiola* phase is not well developed, and includes bands of standard limestone, but the Whitehead limestone (C_2) constitutes a well-marked *Modiola* phase, the algal development being one of the most remarkable in Britain.

In the outcrop south of the Pembroke coalfield (Tenby, &c.) *Modiola* phases are thinner than in most of the country farther east, but occur at the same general levels Km, C_2 and top of S_2. The Km phase is recognisable throughout except at Freshwater West; the C_2 phase is thin along the northern outcrop (West Williamstown and Tenby), and is absent south of Tenby. The S_2 phase is present throughout, but poorly developed in the southernmost outcrop.

[32] F. S. Wallis, *Geol. Mag.*, vol. lxi. (1924), p. 218.

The Yoredale rocks of Wensleydale include typical algal 'lagoon-phase' deposits intercalated with the standard limestone, shale and sandstone, but the finest development of such deposits in the north of England hitherto described is that of the *Solenopora* sub-zone of Garwood at Shap and Ravenstonedale.

In the Winnipeg report it might appear that each of the three facies—standard, Zaphrentid and Culm—is to be regarded as a phasal equivalent. Dixon,[33] however, points out that this was not quite the sense in which Vaughan intended the expression to be used. He did not regard the standard limestones as a phase, but applied the term only to the Zaphrentid and Culm developments. I can see no reason why the calcareous development, even though recognised as 'standard' in Vaughan's sense, is not to be regarded as a phase exactly as with the other phases.

D_3 is the horizon of greatest importance from the point of view of these phasal equivalents. The symbol D_3 was first used by Sibly for rocks in the Midland area overlying D_2. These rocks are of Zaphrentid-phase type, and it has hence been frequently assumed that Sibly intended to restrict the symbol D_3 to rocks of this character. I have never been able to see that there was anything phasal in his original use of the symbol, and he informs me by letter that the symbol was, as I imagined, originally employed in a chronological, not phasal, sense. This usage was not, however, adhered to. Vaughan, while originally using the symbol in a chronological sense, subsequently, as in the Loughshinny paper, employed it in a phasal sense as indicating rocks of Zaphrentid phase at any level in the D beds. He employed the symbol Dy in a chronological sense as equivalent to D_1 and D_2. Other authors have followed Vaughan in using D_3 in a phasal sense. Thus the symbol is attached to the Botany Beds in Garwood's vertical section of the succession in the North-west Province, and clearly indicates a phasal use of the term.

The net result of this varying use of these symbols has proved very confusing, and probably no worker would disagree with Sibly and the British Association Committee in recommending that the use of Dy in a chronological sense be discontinued. Sibly,[34] when discussing the nomenclature of the D beds, suggested that, taking the numbers 1, 2, 3 to indicate time divisions, the letters y, x and p should be added to indicate respectively the standard or calcareous phase, the Zaphrentid-Cyathaxonid phase, and the Culm or lamellibranch-goniatite phase. If this method were adopted and were extended to the whole Avonian system it would afford a simple method of stating the character of the rocks at any level or locality, and would be specially useful in the case of developments like those of Loughshinny, Gower and Wensleydale, where more than one phase is represented at a horizon; thus at Gower lower D_3 is D_3x, upper is D_3p. If all phases were dealt with in this way any suggestion that one phase was less important than another might be avoided.

The foregoing account is chiefly confined to the phases of deposition originally recognised by Vaughan. There are, however, other well-

[33] *Geol. Mag.*, vol. lxii. (1925), p. 382.
[34] *Proc. Geol. Ass.*, vol. xxxi. (1920), p. 81.

marked phases or sub-phases, and the whole series may be classified as follows :—

Predominantly limestone.

1. Standard phase.
2. *Modiola* phase (calcareous lagoon-phase).
3. Reef-knoll phase (including the ' brachiopod beds ' of the Midlands).

Partly limestone, partly shale.

4. Zaphrentid and Cyathaxonid phase.

Predominantly shaly.

5. Goniatite-lamellibranch or Culm phase.
6. Radiolarian phase (siliceous lagoon-phase).
7. Shale phase.

Variable—limestone, shale, sandstone, and sometimes coal.

8. Yoredale phase.

Sandy.

9. Massive sandstones.

Of these Nos. 2, 4, 5 and 6 have already been defined, Nos. 7 and 9 require no definition, while No. 3 is defined in the sequel.

The standard phase may be said to consist of limestone, frequently coarse-grained or crystalline, in which fossils are commonly abundant. Some of the chief varieties are crinoidal limestone, coral limestone and brachiopod limestone. Foraminiferal limestone and oolite link these rocks with those of the calcareous lagoon-phase.

The Yoredale phase.—The limestones are sometimes of standard, sometimes of Zaphrentid phase type, and include also calcite mudstones and algal limestones. The standard limestone fauna may be a coral-brachiopod assemblage, or may be mainly a brachiopod fauna or mainly a coral fauna. The fauna of the associated shale may be very much that of the shales of the Zaphrentid phase, but sometimes bands with the goniatite-lamellibranch fauna occur.

The *Cement Stones* of the Northern Province have features linking them to the Zaphrentid phase and to the Yoredale phase. They consist of thin-bedded sandstone and shale, the latter often highly coloured, with bands of argillaceous limestone or cement stone, which is sometimes algal. The fossils, which are somewhat scanty, are mainly of shallow-water type—spirorbids, ostracods, horny brachiopods, and small lamellibranchs and gastropods.

'Millstone Grit.'

As has been emphasised by Prof. Kendall,[35] the rocks alluded to under the name of Millstone Grit are the most difficult of all the members of the Carboniferous series to reduce to any systematic arrangement. The term has been, and still frequently is, used in a purely lithological sense, as indicating the prevalently sandy rocks which sooner or later succeed the prevalently calcareous or sometimes argillaceous rocks of the Avonian. Any general account of the Millstone Grit is quite outside the scope of this address, which will be concerned merely with the relations of the Millstone

[35] *Handbuch der regionalen Geol.*, iii., 1, s. 153.

Grit (*sensu lato*) to the underlying strata. In briefly considering this subject the following regional division is most convenient, viz. :—

1. West of England.
2. South Wales.
3. North Wales, Midlands and Northern Counties.

West of England (see fig. 2).

In the West of England, as is well known, 'Millstone Grit' conditions set in at a progressively lower level as one passes northwards from the Bristol area. Thus in the Avon section[36] and in the Mendips they set in at the top of D_2. At Sodbury, where the section is incomplete, 84 ft. of D_1 limestones are exposed, but in the Wickwar cutting[37] a few miles to the north the early advent of 'Millstone Grit' conditions reduces the limestone to 55 ft. In the Tytherington district[38] and in the Chepstow area Millstone Grit conditions set in at the top of S_2. In the Forest of Dean the Drybrook sandstone (Millstone Grit of earlier authors) is probably

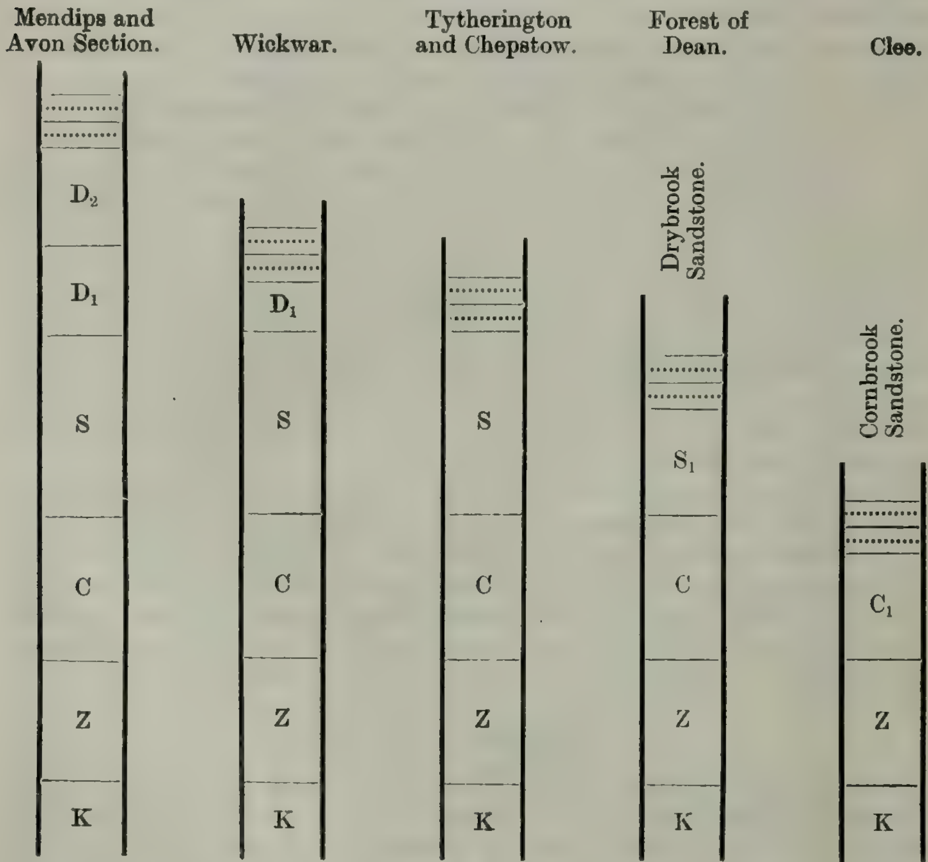


FIG. 2.

TABLE SHOWING THE LEVEL AT WHICH SANDY CONDITIONS SET IN AT CERTAIN LOCALITIES IN THE SOUTH-WEST PROVINCE.

(*Not to scale.*)

[36] *Q.J.G.S.*, vol. lxi. (1905), pl. xxvii.
[37] *Proc. Bristol Nat. Soc.*, 4th ser., vol. vi., pt. 3 (1926, issued for 1925), p. 242.
[38] *Ibid.*, pt. 1 (1924, issued for 1923), p. 64.

of S_2 age. In the Clee Hill district the Millstone Grit facies (Cornbrook sandstone) comes on at about the base of C_2. In all these districts then the ' Millstone Grit ' is wholly or partly (*vide infra*) Avonian.

The thickness of the ' Millstone Grit ' in the West of England is insignificant as compared with the thickness of the rocks generally called by the same name farther north, and it was suggested by Vaughan that it may all be of D_3 age.[39] Recent work[40] shows, however, that the upper part of the ' Millstone Grit ' near Yate contains plants of Yorkian type. This would imply a big unconformity between upper and lower ' Millstone Grit ' of the Bristol area.

Lithologically, as Kendall[41] points out, the quartzose grits and conglomerates which go by this name near Bristol are totally distinct from the arkoses of the Millstone Grit farther north. He consequently suggests that the term ' Millstone Grit' as used in the Bristol area be dropped and replaced by ' Farewell-rock.' There is, however, the objection that the term ' Farewell-rock ' is also used in South Wales, a region where the true post-Avonian Millstone Grit is found; and I am informed by Mr. Dixon and Dr. A. E. Trueman that in parts of South Wales the Farewell-rock is Yorkian in age. Were it not for the fact that the upper beds contain Yorkian plants it would probably be best to use Sibly's term Drybrook sandstone for the ' Millstone Grit ' throughout the whole Bristol area, instead of confining it to the Forest of Dean. The existence of these Yorkian plants necessitates a local name for the Avonian ' Millstone Grit ' of the Bristol district—I suggest the use of the term ' Brandon Hill Grit,' from Brandon Hill, Bristol, where it is well developed. The term ' Farewell-rock ' could be used for the Yorkian portion.

South Wales and the Forest of Dean (see fig. 3).

The Millstone Grit of South Wales shows very remarkable and varying relations to the Avonian.[42] In the south-east part of the South Wales coalfield and in Monmouth it sometimes overlies a big thickness of D beds (Ruthin and Llansannor), sometimes rests directly on upper S_2 (Miskin), sometimes

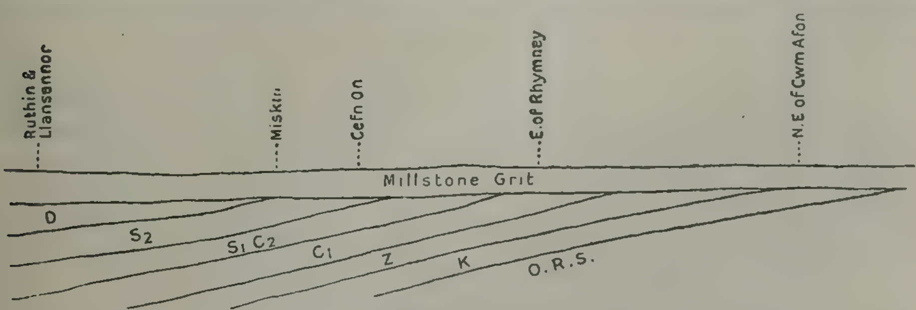


FIG. 3.

Diagram showing Overstep of the Millstone Grit on the south-eastern margin of the South Wales Coalfield. (From figs. and descriptions in the paper by Dixey & Sibly, *Q.J.G.S.*, vol. lxxiii. (1918), pp. 111–164.)

[39] *Rep. Brit. Ass.*, Winnipeg (1909), table 3.
[40] R. Crookall, *Geol. Mag.*, vol. lxii. (1925), p. 403.
[41] *Handbuch der reg. Geol.*, iii., 1, s. 156.
[42] *Q.J.G.S.*, lxxiii. (1917), p. 119.

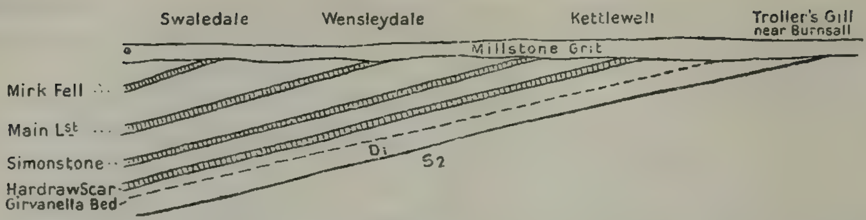


FIG. 4.

Diagram showing Overstep of the Millstone Grit in the Yorkshire Dale and Craven Country. (From information supplied by Mr. R. G. Hudson.)

on the very base of S_2 (Cefn On). This is not, however, due to the coming in of grit conditions at successively lower levels, but, as suggested by Dixon[43] and confirmed by Dixey and Sibly,[44] to overstep. Farther to the north-east the overstep continues to still further reduce the exposed thickness of the Carboniferous Limestone, till at the north-east corner of the coalfield little, if anything, more than the K beds remains between Millstone Grit and Old Red Sandstone. This is the limit of the overstep, as, when followed westward along the north crop, the Millstone Grit rapidly retrogresses, with the result that all the zones up to S_2 reappear in a distance of six miles, and farther west the D beds are seen. Still farther west, however, overstep again sets in, Mr. T. N. George informing me that at Penwyllt (Tawe Valley) the Upper Limestone Shales or rottenstones (D_{2-3}) are cut out by overstep and the Millstone Grit rests directly on D_2. Finally at a point about three miles east of Kidwelly it oversteps down to about the base of D_2.

At Pendine, to the west of Carmarthen Bay, it again rests on D_3, but at Haverfordwest it rests on S_2.

In the Forest of Dean there is no Millstone Grit seen, owing to the overlap of the Coal Measures, which may overstep all the Avonian rocks till they come to rest on the Old Red Sandstone.[45] The Coal Measures play in the Forest of Dean the part which is played by the Millstone Grit in the South Wales coalfield.

North of England.

In the Yorkshire dales it has long been known that the beds of the Yoredale series immediately below the Millstone Grit disappear in succession southwards, the Grit thus appearing to become established at lower and lower horizons in that direction. The officers of the Survey, especially Dakyns and Clough, realised this, but Goodchild[46] was the first to show that it was due to unconformable overstep of the Millstone Grit, and this fact has been fully established by later workers,[47] by whom it has been shown that the Millstone Grit of North-West Yorkshire rests in

[43] *Newport Memoir*, 2nd ed., p. 20.
[44] *Q.J.G.S.*, lxxiii. (1917), p. 157.
[45] Sibly, *Geol. Mag.*, Dec. v., vol. ix. (1912), p. 421.
[46] Victoria County History, Cumberland, *Geology*, 1901, p. 28.
[47] See L. J. Chubb and R. G. S. Hudson, 'The Nature of the Junction between the Lower Carboniferous and the Millstone Grit of North West Yorkshire,' *Proc. Yorks Geol. Soc.*, n.s., vol. xx., pt. 2, 1925, p. 257; and L. H. Tonks, 'The Millstone Grit and Yoredale Rocks of Nidderdale,' *ibid.* p. 226.

succession on all the Avonian rocks from the Mirk Fell beds, which are high up in the Yoredalian above the Fell Top limestone, to strata probably as low down as D.[48] (see fig. 4). Mr. Hudson informs me that unpublished work shows a continuation of this overstep south of the Craven faults in the region of Troller's Gill, near Burnsall, on to the base of D_1 and almost on to S_2. Mr. Hudson's work also shows overlap of the successive zones of the Millstone Grit, the *pseudobilinque* zone of Bisat (lower E) resting on the Avonian at Craven, while at Grassington and Arkendale the *bisulcatum* zone (upper E) is the lowest level represented.

While the stratigraphical level at which the so-called 'Millstone Grit' of the South-west Province comes on is so variable, the base of the true Millstone Grit seems to be at a fairly constant stratigraphical horizon throughout South Wales and the North-western and Northern Provinces. The evidence now available from so many areas shows that the unconformity between Millstone Grit and Avonian which was first observed by Prof. O. T. Jones[49] in the Haverfordwest area is of widespread occurrence, and the establishment of this very important fact has helped and will help to the solution of many problems in Carboniferous stratigraphy.

There are cases in the North of England where beds with fossils of a characteristically Avonian facies overlie some considerable thickness of grit. This may in some cases be due to early establishment of grit conditions, in other cases to a late survival into Lancastrian times of Avonian types. Thus the Snebro Gill beds[50] of West Cumberland which overlie some 50 ft. of grit are considered by Mr. Dixon to be high in the Yoredalian, but the evidence as to their age is admittedly inconclusive, and Mr. Bisat is inclined to correlate them with the Cayton Gill beds (Lancastrian). In Teesdale, Prof. Garwood's Botany Beds,[51] with a late D fauna, are believed to overlie strata about 200 ft. thick originally mapped as Millstone Grit.

In Yorkshire, when circumstances were favourable, a marine fauna temporarily invaded regions[52] where Millstone Grit conditions were thoroughly established. Thus Hind[53] described the Cayton Gill beds of Nidderdale, which lie just below the Kinderscout grit equivalent and have an Avonian type of fauna. The goniatite fauna of these beds is not sufficient to enable Mr. Bisat to speak confidently as to their age, but he suggests lower R.[54] The Colsterdale[53] marine band of the same area, with a goniatite-lamellibranch fauna, is assigned by Mr. Bisat[54] to his horizon E. Again, the Shunner Fell limestone[55] of Yorkshire contains a coral and brachiopod fauna such as is usually found in Avonian rocks of Zaphrentid or Cyathaxonid phase, associated with a goniatite (*Anthracoceras glabrum*) characteristic of zone E of Bisat's table.

[48] Well brought out in Chubb and Hudson's map, *op. cit.*, pp. 282-3.

[49] *Haverfordwest Memoir* (1914), p. 151.

[50] Eastwood (Mem. Geol. Surv.), *Sum. Progress for* 1922, p. 64; and Dixon, *Proc. Geol. Ass.*, vol. xxxvi. (1925), p. 44.

[51] *Q.J.G.S.*, vol. lxviii. (1912), p. 542.

[52] See L. H. Tonks, *Proc. Yorks Geol. Soc.*, n.s., vol. xx., pt. 2 (1925), pp. 226-56, for full references on the marine bands.

[53] Hind, *Naturalist* (1902), pp. 17-63 and 90-96; also Bisat, *Proc. Yorks Geol. Soc.* vol. xix., pt. 1 (1914), p. 20.

[54] *Ibid.*, vol. xx., pt. 1 (1924), pp. 40-124.

[55] Chubb and Hudson, *ibid.*, pt. ii. (1925), p. 261. Other references are given.

But, in addition to these brief and local minglings of Avonian and Lancastrian, evidence is accumulating to show that the upper Yoredalian was synchronous with the lower Lancastrian ; in other words, that the Yoredale type of deposit was being laid down in parts of Yorkshire while Mr. Bisat's lower E beds were accumulating elsewhere. If this is established it will mean that the upper Yoredalian is not Avonian at all, but Lancastrian, and will render it more possible to regard the D_3 and D_3p beds of the Midlands and South as the time equivalent of the Yoredalian, reduced as it will then be by the separation of its Lancastrian portion.

The Dibunophyllum Zone (*sensu lato*) and its equivalents in the North of England.

While, as regards the pre-*Dibunophyllum* beds, the calcareous phases in England and Wales are far more important than any other phase, when we come to the *Dibunophyllum* beds this is not so, at any rate in the North of England, where rocks predominantly shaly are fully as important as those of the calcareous phases.

While, too, in the South-western Province the difficulties of correlation are comparatively slight, when we reach Yorkshire this is far from being the case, and much difference of opinion exists even on major questions of classification and correlation. To clear up these difficulties, a Committee of this Association was appointed, and a report, mainly drawn up by Mr. R. G. S. Hudson, the secretary, was issued at the Southampton Meeting last year. Largely owing to the still imperfect state of our knowledge, it proved impossible to obtain general agreement among the members of the Committee, and two sub-reports dissenting from certain parts of the main report are appended. These differences of opinion are partly on questions of terminology, partly as to the correlation and subdivision of the strata. The various proposals will be found in the Report of the British Association Committee, and in Mr. Cosmo Johns' paper in the *Naturalist* of July 1926. Little is to be gained by recapitulating these in detail. The main thing to strive for is to avoid increasing and, if possible, to lessen the existing confusion. Some of the chief questions at issue are :—

(1) As regards 'Yoredalian.' Is the term to be used ? If so, what are its limits to be ? Is it to be (*a*) a major division of the Lower Carboniferous equivalent to the Tournaisian and Viséan, or (*b*) a subdivision of the Viséan equivalent to the D zone and S zone, or (*c*) an alternative name for the highest part of the D zone, equivalent in fact to an extended D_3 ?

(2) Is it desirable to adopt the zone O (of *Orionastræa phillipsi*) as proposed by the B.A. Committee ?

(3) What are the best levels to take for delimiting D_1 and D_2 ?

(4) If the term Yoredalian is adopted, is D_3 also necessary ? or may D_3 as far as the northern development is concerned be merged in Yoredalian ?

We have in the first place Phillips' main division into Great Scar Limestone and Yoredale Series, based on obvious differences conspicuous throughout the greater part of the area, though, as he recognised, this is not the case in part of the south-eastern section, owing to the lower members of the Yoredale series being represented by massive limestone.

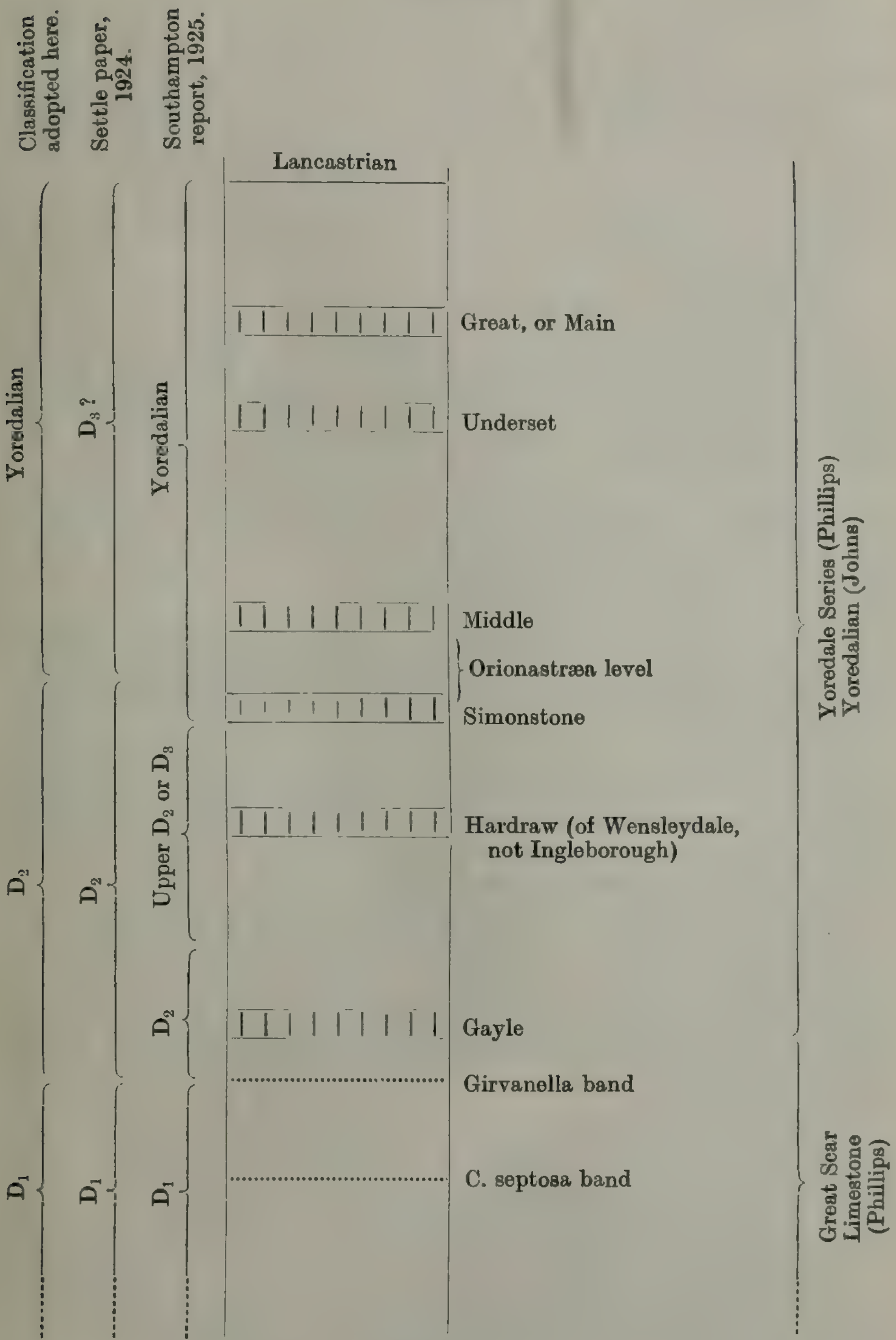


Fig. 5.

Classification of the Uppermost Avonian (calcareous phases) of Yorkshire.

I think there can be no doubt as to the desirability of the use in Yorkshire of the term Yoredale Series or Mr. Cosmo Johns' variant Yoredalian. Its top must clearly be taken as the level of entry of the Lancastrian fauna of Upper Carboniferous type defined by Bisat.

As regards the level to take as the base of the Yoredalian, the difficulty is increased by the uncertainty as to what significance is to be attached to the expressions 'top of D_2' and 'top of D_3.' The top of D_2 in the Settle paper is just below the *Orionastræa* band (Simonstone limestone level), while in the Southampton report the *Orionastræa* band is the top of D_3 (or 'upper D_2').

The level taken as the top of D_2 (and base of the Yoredalian) by Mr. Johns is in the shale below the Hardraw limestone, which he says corresponds exactly with the base of the Yoredale series as defined by Phillips, and with the base of Bisat's zone P. I am informed, however, by Mr. Hudson that the latter argument no longer holds, recent goniatite work having shown that part of D_2 is to be correlated with lower P. The chief argument in favour of Mr. Johns' proposal is the admitted convenience of the base of the Yoredalian coinciding with a well-marked change in lithology, and with the base of the Yoredale series of Phillips.

On the other hand the following facts tell in favour of the adoption of the *Orionastræa* level as the top of D_2 :—

1. It is a level having as a rule a well-marked palæontological character.

2. If this level be adopted, D_2 forms a subdivision of considerable thickness and includes both the upper and lower *Lonsdaleia* beds, instead of only the lower.

3. This is the level adopted for the top of D_2 in the two most important papers published in recent years on the northern succession, viz., that on the Carboniferous Succession in the North-west Province by Prof. Garwood, and that on the Lower Carboniferous Succession in the Settle district by Prof. Garwood and Miss Goodyear.

4. The level appears to coincide with the horizon of important stratigraphical events, such as the Derbyshire and Cracoe unconformities.

In view of these facts, I think that, on the whole, the best course to pursue is to commence the Yoredalian at the base of the *Orionastræa* level and to include all between that level and the *Girvanella* level in D_2. There would then be no need to use the expression D_3 in Yorkshire and the North-west Province.

The chief argument for giving the Yoredalian the status of a major division of the Avonian equivalent to the Tournaisian and Viséan is its thickness and importance in the North of England. If, however (*vide supra*), the Yoredalian is to be reduced by including its upper portion in the Lancastrian, the argument loses much of its force. As was pointed out by the authors of the sub-reports, the Yoredalian is not sufficiently marked off faunistically or otherwise to merit its recognition as a major division. The fauna is essentially a D fauna, and, in spite of its thickness and importance in the North, I think there is nothing for it but to group it with the D beds.

I do not feel capable of expressing an opinion as to the desirability or otherwise of recognising the zone O. The fact that *Orionastræa* is found

in the Bristol district, Midlands and North Wales at a lower level (D_2) than the proposed zone O is no valid argument against its adoption.

There is, I think, no difference of opinion as to the limits of D_1; it begins with the entry of the D-coral fauna, and particularly of *Cyathophyllum* (*Palæosmilia*) *murchisoni*, and ends below the *Girvanella* bed.

The following classification of the chief limestones of the North of England is drawn up with the aid of Dr. S. Smith.

D_1, *the sub-zone of Cyathophyllum murchisoni.*—The base of D is marked by the entry of the D-coral fauna. D_1, which in Westmorland has at the base a well-known level, the Bryozoa bed of Garwood, includes part of the Great Scar limestone of Yorkshire, part of the Melmerby Scar limestone series of the North-West Pennines, and all the strata from the Redesdale and Woodend limestones at the base to the Oxford limestone at the top in Northumberland. In West Cumberland it includes the sixth and fifth limestones, and the lower part of the fourth up to the base of the *Girvanella* nodular bed.

D_2, *the Lonsdaleia sub-zone* of Vaughan's original classification, is divided into lower D_2, the sub-zone of *Lonsdaleia floriformis* (lower *Lonsdaleia* beds); upper D_2, the sub-zone of *Lonsdaleia duplicata* (upper *Lonsdaleia* beds). The *Girvanella* nodular bed, which is very well marked throughout much of Yorkshire and the North-west Province, is found also in Northumberland (Oxford limestone), and forms an admirable datum line for the base of D_2. The top of D_2 will lie just below the *Orionastræa* level, and in D_2 will be included all strata from the *Productus giganteus* to the *Productus edelbergensis* beds of the Settle district, the Gayle, Hardraw, and lower part of the Simonstone levels of the Dale country, and in Northumberland from the level of the Oxford limestone to that of the Eelwell and Tynebottom limestones.

The *Yoredalian* under the scheme here adopted includes the *Orionastræa* zone and others not yet defined of the Southampton report, and extends on to the base of the Lancastrian. In the Settle area it includes the strata from the *Orionastræa* level (Simonstone) to the Great, Upper Scar, or Main limestone, and in the Dale country also strata above the Main limestone. In the Alston district and in South Northumberland it includes the succession from the Tynebottom to the Fell Top limestone. As has been already pointed out, some of these strata may prove to be of the age of the lower Lancastrian.

The Shaly development (*Goniatite or Culm phase P*).

Rocks of this phase form the large Culm area of North Devon, and in the North much of the contiguous parts of Yorkshire, Lancashire, and Derbyshire, the type area being that of Pendle Hill and Clitheroe.

Although Wheelton Hind devoted much time to their study, they were, until a comparatively few years ago, relatively neglected by workers on the British Carboniferous rocks, but, thanks primarily to Mr. W. S. Bisat's work on the goniatites, this is far from being the case at the present time, and their succession is now known with an accuracy and detail which has often not yet been reached in areas where the rocks are of the calcareous phase. Mr. Bisat's work on the goniatites, following on

the earlier work of Wheelton Hind in England and of Haug in France, shows them to have a value for zonal purposes in the Upper Carboniferous comparable to that of the graptolites in the Lower Palæozoic and the ammonites in the Mesozoic. It may be safely stated that his paper on the Carboniferous goniatites of the North of England is by far the most important contribution to Carboniferous stratigraphical palæontology which has appeared since Vaughan's classical paper.

Goniatites are on the whole characteristic of the Upper Carboniferous, and it is not till quite near the end of Avonian times (D_2 or D_3) that they appear in British Carboniferous rocks in any number. As far as I know, not a single goniatite has been found in the Avonian rocks of the Bristol area, although in D_1 and D_2 are thick shales in which they might be expected to occur. The D_3 beds of the Bristol district are unfossiliferous quartzites or grits, but the Lower Coal Measures of Ashton,[56] near Bristol, include marine bands with a typical Culm assemblage, including goniatites.

Although the non-occurrence of certain forms may commonly be due to unsuitability of physical conditions, the best explanation of these facts seems to be to conclude that goniatites did not migrate into the Bristol area till Lower Coal Measure times.

While as a rule the calcareous coral and brachiopod facies and the shaly goniatite facies are sharply defined, rendering correlation a matter of great difficulty, it has long been known that goniatites appear sparingly in the Knoll limestone of Craven and the Yoredale series of Settle and Wensleydale. Bands with the goniatite facies are occasionally, as at Budle Bay, intercalated in the upper Bernician series of Northumberland. In the classical area of Pendle Hill, originally described by Hind and Howe, and recently restudied by Parkinson, both calcareous and goniatite phases are represented.

Although as regards the highest Avonian rocks, in view of the difficulty of correlating the deposits of the two chief phases, the standard phase and the goniatite-lamellibranch or Culm phase, it is clear that two time scales and two sets of zonal indices are for the present necessary I think few workers on the Avonian will disagree as to the desirability of eventually correlating all phases in one scale. Further, I think there will be few to dispute that, partly as it is only in the case of the uppermost Avonian rocks that a goniatite scale is necessary or proposed, partly owing to the fact that modern work on the Avonian rocks was first put on a firm basis by the study of the standard or calcareous phase, it is this development with which other facies should be compared, and as far as possible correlated. For the Lancastrian deposits no one can doubt that the goniatite succession is the one with which any others must be correlated.

The use of the symbol P may next be considered. Some authors have used it in a chronological sense, others in a phasal sense, and others again, including its original users Vaughan and Matley, partly in a chronological and partly in a phasal sense. Vaughan and Matley first used it in 1908 for strata at Loughshinny above D_2 in which a Zaphrentid or Cyathaxonid facies alte nated with a lamellibranch or Culm facies.

[56] H. Bolton, *Q.J.G.S.*, lxiii. (1907), pp. 445–69, and lxvii. (1911), p. 337.

In the Gower paper[57] P is used primarily in a chronological sense for strata succeeding D_{2-3}, while Sibly[58] suggests its use in a purely phasal sense.

The zone P was re-defined by Bisat[59] in a strictly chronological sense as the zone of *Goniatites crenistria*, and probably that of any member of the genus *Goniatites* (*sensu stricto*). This use is somewhat more restricted than that of the Loughshinny paper, but wider than that of the Gower paper. It is thus clear that there has been no uniformity in the use of P, and probably it would really be best if, as Dixon[60] suggested, the symbol as used in a chronological sense were dropped, and, as Sibly proposed, it were used purely in a phasal sense for Avonian rocks displaying the Culm or goniatite development. The successive zones might then (as Dixon proposed) be alluded to by the zonal fossil, as is done with the graptolites of the Lower Palæozoic and the ammonites of the Mesozoic.

It cannot, however, be expected that such a course should commend itself to the workers on the Culm-goniatite development, particularly in view of the already extensive literature based on Mr. Bisat's work. It seems to me that both zone P and Yoredalian are north-country denominations, and that in the south it would be more convenient to designate their equivalents D_3p and D_3y.

Reef Knolls.[61]

The general facts regarding reef knolls are well known. They are highly fossiliferous limestone, in certain cases dolomite, hills or mounds, the fossils being exceptionally well preserved. 'The term reef as used in these cases implies that, though not composed of corals, the masses have undoubtedly caused local elevations at the bottom of the Carboniferous sea' (Dixon).[62] In some cases the stratification shows a quaquaversal dip, and the massive and frequently crystalline limestone of which the reefs are composed is succeeded in all directions by rocks of the Zaphrentid phase—thinly-bedded limestones and shales.

Mr. Hudson, in describing the Cracoe knolls, says that the characteristics of reef limestone are seen in its irregular non-bedded nature, in the contemporaneous breccias, in the frequent shell-beds of rolled and broken Productids, and in the abundant pockets packed with shells in perfect preservation, often showing colour bands and evidently in the position of growth. He remarks that the frequent occurrence of sheets of calcareous tufa points to deposition in shallow water or even to emergence.

Such reefs are met with in the Lower Carboniferous rocks at a number of localities in the British Isles, but particularly in West Yorkshire, in the South Craven area between Skipton and Malham, and in the Cracoe and Burnsall areas between Skipton and Grassington, and in the Bowland

[57] *Cf.* table facing p. 105.

[58] *Proc. Geol. Ass.*, xxxi. (1920), p. 81.

[59] *Op. cit.*, pp. 43-5.

[60] Southampton *Report*, sub-report i.

[61] *Note.*—Dr. D. Parkinson's paper on the 'Faunal Succession in the Carboniferous Limestone of Clitheroe,' *Q.J.G.S.*, vol. lxxxii. (1926), pp. 188-249, contains an important account of the Clitheroe knolls.

[62] *Pembroke and Tenby Memoir*, p. 68.

and Clitheroe areas. Other examples occur at Poolvash, near Castleton, Isle of Man, while the Waulsortian of Belgium, part of the *Syringothyris* beds of Co. Clare, and the well-known brachiopod beds of the Midlands[63] (Treak Cliff, Castleton, Park Hill, near Longnor, Thorpe Cloud, in Derbyshire, Narrowdale, near Wetton, and Cauldron,[64] in Staffordshire), and those of St. Doulagh, near Dublin, are analogous.

From South Wales, Dixon [65] describes in C_1 reef dolomites largely of bryozoal origin and a small limestone reef of C_2 age, the relations of which to the surrounding rocks of the Zaphrentid-phase are particularly well seen.

The Waulsortian of Belgium is described by Vaughan[66] as 'composed of thick irregular accumulations of powdery limestone often brecciated and seamed with calcite veins; its most striking aspect is a massive limestone, mottled with bluish blotches rich in Fenestellids. Every now and then the beds swell out into mushroom-shaped lenticles of unstratified reefs (the "knolls") roofed over by the next stratified deposit, which spread over the uneven floor.'

Both in Britain[67] (S. Wales and Clitheroe) and in Belgium[68] a peculiar laminar structure occurs associated with the Fenestellids of the reef dolomites. The significance of this is not yet understood. Fenestellids, though generally characteristics of reef-knoll limestones, are not common in the Cracoe knolls.

It was observed by Tiddeman,[69] who first described them, that the knolls do not all lie on the same horizon. He divided them into two groups—an upper series which he grouped with the Pendleside limestones, and a lower series included in the Clitheroe limestone. Vaughan[70] maintained that Tiddeman's upper group is of D_2 age, and showed that his lower group included two distinct series, an upper series of S age and a lower series of C age. Dr. Parkinson's recent work is in accord with that of Vaughan as to the age of the Clitheroe knolls.

With few exceptions recent workers are agreed that Tiddeman's original views as to the origin of reef-knolls are essentially correct. He held that they are due to the original deposition of the remains of calcareous organisms in an area undergoing depression, not to any subsequent packing by earth movements, as was maintained by Marr.[71] Tiddeman's theory was originally supported by Dakyns, and received weighty confirmation from Vaughan, who showed that there is a special reef-facies easily recognisable as such, whatever the level may be from which the specimens are derived. Gastropods and lamellibranchs, sometimes bryozoa and trilobites, and in particular certain persistent brachiopods (*Pugnax, Schizophoria, Martinia*), which often attain an exceptional size, abound in these reef deposits, but corals, with the exception of *Amplexus*, are rare.

[63] *Q.J.G.S.*, vol. lxiv. (1908), p. 49.
[64] *Geol. Mag.*, vol. lviii. (1921), p. 367.
[65] *Pembroke and Tenby Memoir*, p. 127.
[66] *Q.J.G.S.*, vol. lxxi. (1915), p. 12.
[67] Dixon, *Pembroke and Tenby Memoir*, p. 127.
[68] Delépine *MS.*
[69] *Rep. Brit. Ass.*, Newcastle, 1889, p. 602, and Bradford, 1900, p. 740.
[70] *Proc. Yorks Geol. Soc.*, vol. xix. (1916), pp. 41-50.
[71] *Q.J.G.S.*, vol. lv. (1899), pp. 327-58.

Vaughan[72] gives a list of species characteristic of reef knolls in general, and further lists of those characterising Tournaisian and Viséan knolls respectively. It remains to be seen whether any comparison can be made between the physiographic relation of Avonian reefs and those of the coral reefs of our own time.

Distribution of Reef Knolls and Limestone.

D

South Craven Area.

Cracoe neighbourhood: Swinden, Skelterton, Stebden, Butterhaw, Carden.
Burnsall neighbourhood: Elbolton, Thorpe Kail, Hartlington Kail.
Grassington neighbourhood: Thorpe to Hebden.[73]
Gargrave neighbourhood: Fogger,[73] Crag Laithe.[73]
Malham neighbourhood: Cawden, Wedber.
Settle neighbourhood: Scaleber.

Midland Area.

Wetton, Thorpe Cloud.

Isle of Man.

Poolvash.

D or high S

Bowland Area.

Ashnott.

S

Bowland Area.

Dunmow, near Slaidburn, Knowlmere.

Clitheroe Area.

Salt Hill, Crow Hill, Worsaw, Withgill, Gerna, Sykes, Twiston.

C

Clitheroe Area.

White Croft Wood, Waddow, Coplow.

Pembrokeshire.

Freshwater West.

Pseudobreccia.

This well-known rock type, originally described by Tiddeman[74] and subsequently and much more fully by Dixon,[75] is very characteristic of the D beds, particularly of D_1, throughout the whole South-western Province. While, perhaps, best developed in Gower, where these rocks

[72] *Q.J.G.S.*, vol. lxxi. (1915), p. 13.
[73] Mr. Hudson informs me that these are not true knolls, but are local developments of limestone of reef type. Similar developments occur at other places in the Craven lowlands.
[74] *Swansea Memoir*, p. 10.
[75] *Q.J.G.S.*, vol. lxvii. (1911), p. 507.

were first described, they are typically exposed in the Avon section, in South Pembrokeshire and many other localities. The following is in the main an abstract of Dixon's account. The rock consists of patches (' fragments ') of dark limestone generally crowded with foraminifera, surrounded by lighter and more argillaceous limestone (' ground mass or matrix '), the two generally occurring in approximately equal proportions. Both ' fragments ' and ' matrix ' consist essentially of a calcareous mud, and microscopic examination shows that the outline of the ' fragments ' is not sharp and well defined, but that they shade off into the ' matrix.' The material of both ' fragments ' and ' matrix ' is partly recrystallised, but the change has affected the ' fragments ' more than the ' matrix,' tending to slightly clarify them, and has been accompanied by concentration of the argillaceous and ferruginous material in the ' matrix.' This recrystallisation is believed to have taken place shortly after deposition. The patchy distribution of pseudobreccia, its widespread occurrence on the same level, and the fact that the ' matrix ' has often been dolomitised while still under the influence of the Avonian sea, point to this conclusion. Dolomitisation tends to increase the appearance of brecciation ; indeed, it was the emphasising of their structure by contemporaneous dolomitisation which first drew Tiddeman's attention to pseudobreccias. Pseudobreccia often passes laterally into what has been termed in the Gower area ' clay with rubble,' and in the Avon section ' rubbly limestone.' These bands, which are very discontinuous, consist of rounded masses of limestone often several inches in diameter, embedded in a red shaly matrix ; they probably owe their character to a concretionary or recrystallisation process whereby the lime gathered in nodules, from which the iron and shaly material became separated. The characters are emphasised by weathering.

There are other noteworthy features shown by weathered pseudobreccia. The more coarsely crystalline character of the ' fragments ' renders them relatively resistant to chemical change, so that they stand out prominently on the weathered surface. This is well seen both in Gower and the Avon section. A more remarkable feature is the deep pitting of the bedding planes, best known from Gower, where it was originally described by Tiddeman,[76] but also very well seen at Mells in Somerset. These pits are roughly circular, and as described from Gower are 18-30 inches in diameter and a foot deep. The Mells examples are rather wider and shallower. In each case they contain some clay, and it is suggested that they, like the rubbly limestone, may be an expression of a process of recrystallisation leading to a local concentration of the argillaceous material. Mr. Dixon, however, informs me that after seeing the pot-holed limestones of the Whitehaven district he believes that the Gower pitting is shallow pot-holing.

Pseudobreccias, though mainly met with in foraminiferal limestones of D_1 age, may also occur at other horizons and in other kinds of limestone. High up in D_2 in the Avon section[77] is a band of sandy limestone showing pseudobrecciation in which recrystallisation has led to the concentration of sandy and ferruginous material in the ' matrix,' while in the more usual type of pseudobrecciation it is argillaceous material that is so

[76] *Swansea Memoir* (1907), p. 10.
[77] *Q.J.G.S.*, vol. lxxvii. (1921), p. 235.

concentrated. The honeycomb sandstone described by Cantrill[78] which occurs at the base of D_1 along part of the North Crop of the South Wales coalfield seems to be similar. A second exceptional case of pseudobrecciation in the Avon section occurs on a small scale in the *Cleistopora* beds, some four feet above the base of the Bryozoa bed. In this case the change has led to much separation of iron and some of argillaceous material. The rock affected is a crinoidal limestone.

The prevalence of pseudobreccias in the D_1 beds of the Midlands and the North-west Province, as well as in the South, is one of the features emphasising the uniformity of conditions which apparently prevailed in the Avonian seas of England and Wales at this time.

Though pseudobreccias are not alluded to as such in the Anglesey Memoir, the term not having been introduced when the field work was in progress, Dr. Greenly informs me that they are extensively developed both at the top and near the bottom of D_2. They are alluded to in the Memoir as mottled limestone.[79] Pseudobreccias occur in the Lilleshall limestone (D_2), but, as Mr. Wedd informs me, are characteristic and apparently confined to the 'White Limestones' (upper D_1 and lower D_2) of Denbigh and Flint. In the southern part of the area they mark a well-defined and persistent horizon near the top of the 'White Limestone.'

Typical pseudobreccias are described by Jackson[80] from the upper D_1 of the Miller's Dale area, Derbyshire.

Garwood[81] describes from the D_1 beds of the North-west Province certain structures under the names of (1) spotted beds, (2) pseudobreccias, saying that the two occasionally pass into one another. The spotted beds are of two types; in the first the spots consist of small spherical patches of darker limestone surrounded by a lighter matrix, the two grading into one another. No constant difference between spots and matrix was detected beyond the concentration of the coloured impurities in the spots, this being attributed to slight concretionary action. The second type of spotted bed, which is far less common, differs in the fact that the original rock contained a considerable amount of sandy material. Concretionary action in this case has led to the concentration of the sand grains in the matrix, while the colouring matter as in the first case collected in the spots. In each case the process is believed to be contemporaneous. The structures described appear to be identical with those of the South-west Province.

Pseudobreccias are known from many other localities in the D_1 beds of the North of England; thus Garwood and Goodyear[82] describe them from the Great Scar limestone of the Settle area, and Edmonds[83] from Cumberland, while they occur also in the Dale Country (Wensleydale).

In West Cumberland they are found at many levels in the D beds and extend up to D_3.

Though nodular structures suggesting pseudobrecciation are present in some dark limestones, the structure is only typically developed in beds

[78] *Ammanford Memoir* (1907), p. 69 *et seq.*
[79] *Anglesey Memoir*, vol. ii. (1919), p. 606.
[80] *Geol. Mag.*, vol. lix. (1922), p. 467.
[81] *Q.J.G.S.*, vol. lxviii. (1912), p. 476.
[82] *Ibid.*, vol. lxxx. (1924).
[83] *Geol. Mag.*, vol. lix. (1922), p. 80.

free from dark mud, but we have still to learn what were the conditions that determined its formation.

Algal Limestones.

Mr. E. B. Wethered and the late Prof. H. A. Nicholson were the earliest British workers to pay attention to the calcareous algæ and other somewhat obscure organisms which are met with in the Carboniferous Limestone. But it was not till Prof. Garwood turned his attention to the subject that their importance as rock-builders was fully recognised. His presidential address to Section C (Birmingham, 1913) and papers in the Geological Magazine[84] have led to the recognition of these organisms at several horizons and in many localities.

In the North-west Province, Garwood describes[85] well-marked algal developments at three levels, viz.: (1) the *Solenopora* sub-zone (lower C_1), (2) near the base of the *Seminula gregaria* sub-zone (lower C_2), and (3) the *Girvanella* nodular bed (base of D_2) which forms the top of the Great Scar limestone.

The *Girvanella* band is met with in many of the Yorkshire dale sections, and occurs in the equivalent of the Great Scar limestone of other areas, such as the Melmerby scar limestone of Alston, and the Oxford limestone of North Northumberland.

Algæ also occur at the base of D_1 in the Woodend, Redesdale and Dun limestones of Northumberland. In the Berwick-on-Tweed Memoir *Girvanella*-like nodules are recorded from several levels.[86]

Garwood[87] mentions that *Mitcheldeania* is found in the highest calcareous bands of the Cement Stones at a number of localities in Northumberland.

The rhythmic succession in the Yoredale series of Wensleydale, described by Hudson,[88] ends in each case with algal limestone deposited under shallow-water conditions. His table of succession shows such bands in the Middle, Simonstone, Hardraw Scar, and Gayle limestones. There are also indications of a rhythmic succession in the Northumberland sequence. In West Cumberland algal bands occur at a number of levels. Edmonds[89] mentions three principal ones in addition to the *Girvanella* band at the base of D_2.

A study of the rocks of the Avon section[90] has shown that a strong algal development occurs at three levels, Km, C_2-S_1, and the top of S_2. The well-known ‘ concretionary beds ’ at the top of S_2, and the pisolites which occur at various levels in S_1 and S_2, were shown to be—in part, at any rate—algal. Algal limestones have been recognised in all the other Carboniferous Limestone sections in the Bristol district that have been studied in detail wherever rocks deposited under *Modiola*-phase conditions occur. Thus algal limestones occur in both S_1 and S_2 in the Wickwar

[84] Dec. v., vol. x. (1913), pp. 440, 490, 545, and Dec. vi., vol. i. (1914), p. 265.
[85] *Q.J.G.S.*, vol. lxviii. (1912).
[86] *Mem. Geol. Surv.*, Berwick-on-Tweed (1926), pp. 18 and 23.
[87] *Geology in the Field*, p. 676.
[88] *Proc. Yorks Geol. Soc.*, vol. xx., pt. 1 (1923-24), p. 125.
[89] *Geol. Mag.*, vol. lix. (1922), p. 119.
[90] *Q.J.G.S.*, vol. lxxvii. (1921), and *Geol. Mag.*, vol. lviii. (1921), p. 546.

area,[91] that in S_2 at Bury Hill being one of the finest in the Bristol district. In the Burrington section algal layers were found only in S_2, and in the Sodbury[92] section in C_2-S_1 and S_2.

The algal development of the Whitehead limestone at Mitcheldean is perhaps the most remarkable in the South of England. In the Pembroke and Tenby district[93] algal limestones occur in the K and C_2-S_1 beds, while the S_2 pisolites of the Kidwelly area are doubtless algal.

Dolomitisation.[94]

This subject would by itself afford sufficient material for several presidential addresses. I make no attempt to deal with the general question, and in particular cannot discuss the important results obtained by American investigators of coral-reef dolomitisation. My aim is merely to summarise some recent work on British Carboniferous dolomites and provide a brief statement as to their distribution.

The dolomites of South Wales were very carefully studied by Dixon,[95] while those of the Midlands are fully described by Parsons.[96] These authors agree as to the general classification of dolomites, Parsons dividing them into :—

1. *Primary*, including
   (*a*) Those deposited as clastic rocks derived from some pre-existing dolomite.
   (*b*) Those chemically precipitated as dolomite.
2. *Secondary*, including
   (*a*) *Contemporaneous*, *i.e.* rocks deposited as ordinary limestones but dolomitised soon after deposition.
   (*b*) *Subsequent*, *i.e.* rocks dolomitised at some later period.

Primary dolomites are of comparatively slight importance among Avonian rocks, but, according to Dixon,[97] include dolomite-mudstones and reef dolomites. Dolomite-mudstones occur in the *Athyris glabristria* zone of the North-west Province. The reef dolomites of the Tenby district are grey unbedded dolomite-mudstone showing a peculiar association with Fenestellids, which is to be matched exactly in the knoll limestones of Clitheroe and the Waulsortian of Belgium. It is now generally admitted that most dolomites are secondary and contemporaneous, having been produced in part by a process of leeching out of the lime and subsequent concentration of the magnesia, in part by a process of replacement of lime by magnesia derived from sea-water. The occurrence over a wide area of dolomite of constant character points to its contemporaneity, *e.g.* the *laminosa*-dolomite of the South-west Province, while patchy dolomite such as occurs on a large scale in the D beds of Derbyshire is subsequent. The lateral and often abrupt passage into unaltered limestone such as occurs in Derbyshire is also characteristic of subsequent

[91] *Proc. Bristol Nat. Soc.*, 4th series, vol. vi., pt. 3 (1926, issued for 1925), p. 246.
[92] *Geol. Mag.*, vol. lx. (1923), p. 117.
[93] *Dixon, Pembroke and Tenby Memoir*, p. 69.
[94] See F. W. Clarke, *The Data of Geochemistry* (1908), p. 480. Full references.
[95] *Swansea Memoir* (1907), p. 11, and *Pembroke and Tenby Memoir* (1921), p. 70.
[96] *Geol. Mag.*, vol. lix. (1922), pp. 51 and 104.
[97] *Pembroke and Tenby Memoir* (1921), p. 70.

dolomites. In contemporaneous dolomites, which are normally dark grey, the crystals interlock with one another and produce a granular mosaic of allotriomorphic crystals, while in subsequent dolomites, which are normally light grey or reddish, the crystals as a rule tend to be relatively large and idiomorphic. In Derbyshire, however, the thick dolomites claimed by Parsons as subsequent are mainly allotriomorphic. The interbedding of a dolomite with non-dolomitised strata is not necessarily a proof of contemporaneous alteration, for, as Parsons points out, subsequent dolomitisation is capable of affecting a bed while leaving those above and below unaltered.

Organic remains, particularly those which, like crinoidal 'ossicles,' are composed of calcite in fairly large crystals, tend to be more resistant to dolomitisation than the matrix, which is acted on with special readiness if consisting originally of aragonite mud. Dixon[98] shows that in contemporaneous dolomites corals and ooliths are resistant as compared with the matrix, while in subsequent dolomites the corals and ooliths are affected first. In several districts where Triassic rocks rest or have rested on the Avonian, the dolomite crystals are seen to contain hæmatite, presumably derived from the Trias, and affording proof that the dolomite is subsequent; Parsons[99] figures an excellent case of this from Breedon, in Leicestershire.

Selective dolomitisation is a term employed by him when the formation of dolomite occurs in certain portions of the rock, tending to produce a mottled or brecciated appearance, *e.g.* the pseudobreccias of the South-west Province. Cases are known where there is evidence of the secondary addition of Mg. at more than one period; such are termed by Parsons *complex* dolomites.

Distribution of Dolomites.

South-western Province.—There is progressive increase in dolomitisation as one passes northwards from the Mendips and eastward from Pembrokeshire, the phenomenon reaching its maximum in the region south and east of the South Wales coalfield. It is not easy to trace any relation between the amount of dolomitisation and the shore-lines of the period.[100]

In the Burrington section lower C_1 is dolomitised, and there is some dolomite at various levels in S_1.

In the Avon section[101] dolomitisation is widely prevalent throughout Z and γ, without, however, leading to the obliteration of the fossils. Lower C_1 and C_2 are almost completely dolomitised, while there is a good deal at various levels in S. The Sodbury section[102] is essentially the same as the Avon section as regards dolomitisation.

In the Chepstow area Z and C are greatly dolomitised, while there is a good deal in S, especially S_1.

[98] *Q.J.G.S.*, lxxiii. (1917), p. 110.

[99] *Ibid.*, pl. x., fig. 4.

[100] See Vaughan, 'Shift of the Western Shore-lines in England and Wales during the Avonian period,' *Rep. Brit. Ass.*, Manchester, 1915, p. 429.

[101] *Geol. Mag.*, vol. lviii. (1921), p. 544.

[102] *Ibid.*, vol. lx. (1923), pp. 112-3.

In the 'Main Limestone' (Z_1—γ) of the Forest of Dean dolomitisation is very complete,[103] and while chiefly contemporaneous, in the hæmatite-bearing beds where it is at its maximum, subsequent (vein) dolomitisation has been added to the contemporaneous. Along the south-eastern margin of the South Wales coalfield in the Taff Valley, and to the east, there is an almost unbroken series of dolomites extending throughout the whole section from the base of Z to the Millstone Grit. The change is mainly contemporaneous, but in C_2 and S_2 there has been vein dolomitisation. West of the Taff Valley, as at Ruthin, dolomitisation is in the main restricted to Z_1 and C_1.[104]

Throughout Gower[105] C_1 retains the character of the *laminosa*-dolomite of the Avon section, and there is much dolomite in Z_2. In E. Gower Z_1 is also dolomitised, as are to some extent the pseudobreccias of D. There is less dolomite in the S beds of W. Gower than in those of E. Gower.

In the Tenby district,[106] except for the fact that there is little dolomite in Z, dolomites prevail at much the same levels as in Gower, viz., C_1, various levels in C_2 and in the pseudobreccias of D_1. The peculiar reef-dolomite of C_1 has been alluded to above. On the whole, in Pembrokeshire, as in the eastern part of the South-west Province, dolomitisation of the Tournaisian increases northwards.[107] Both in Pembrokeshire and along the north crop of the main South Wales coalfield it is almost wholly absent from the Viséan.

Midland Area and North Wales.

In the D limestones of the Midland area, as Parsons[108] points out, dolomitisation shows two contrasting types. In the main limestone mass of central Derbyshire it is wholly subsequent, while in the marginal deposits of the Leicester coalfield it is almost or wholly contemporaneous.

In North Wales there are no horizons of widespread dolomitisation, but Greenly[109] states that local dolomitisation is not uncommon in Anglesey, and appears to have been, partly at any rate, contemporaneous. On the other hand the masses of dark-brown dolomite of Seiriol and Penmon (top of D_2) are subsequent.

North of England.

In Yorkshire and the North-west Province dolomitisation is comparatively slight. No contemporaneous dolomite is mentioned as occurring in the Settle district, though extensive subsequent dolomitisation has taken place locally in relation to the Craven faults.[110]

Dolomitisation is not a characteristic feature of the North-west Province, but the dolomite mudstones of the *Solenopora* sub-zone (C_1) of the Shap[111] area are characteristic examples of primary dolomites.

[103] *Geol. Mag.*, Dec. v., vol. ix. (1912), p. 419.
[104] Dixey and Sibly, *Q.J.G.S.*, vol. lxxiii. (1917), p. 122.
[105] Gower paper, *Q.J.G.S.*, vol. lxvii. (1911), table facing p. 505.
[106] *Pembroke and Tenby Memoir*, p. 70.
[107] Dixon, *Sum. Prog.* (1906), p. 54.
[108] *Geol. Mag.*, lix. (1922), p. 115.
[109] *Anglesey Memoir*, ii., p. 606.
[110] *Q.J.G.S.*, lxxx. (1924), pp. 210-212.
[111] *Ibid.*, vol. lxviii. (1912), pp. 456 and 487.

In the Whitehaven district[112] subsequent dolomitisation occurs locally in many of the limestones.

There is very little dolomitisation in the limestones of Northumberland and Durham, though Dr. S. Smith informs me that the Great or Dryburn limestone of Beadnell (D_3) shows subsequent dolomitisation.

Chert.

The subject of chert, or even of Carboniferous chert, would alone yield material for a lengthy address. I make no attempt to deal with it exhaustively, and there is the less reason to do so since the publication of Mr. H. C. Sargent's[113] two important papers, which contain full references to the literature, British and foreign.

Distribution, Stratigraphical and Geographical.

In the Culm area of North Devon chert is strongly developed in D_3, where the fauna includes forms characteristic of D_3x and D_3p.

In the Mendip region cherts are plentiful, particularly at the γ level in the Frome area. In the Burrington section chert occurs in Z_1 and is strongly developed in $C_1\gamma$ and S_2. At Vallis there is a great development of laminated chert in Z_2. There is much chert in β and Z_1 at Portishead.

In a large proportion of the North Somerset sections the fossils in Z_1 are much silicified (beekitised), even if massive chert is not present.

Chert is much less developed in the Gloucestershire sections than in those of Somerset. In the Avon section it is not conspicuous, but a little occurs in Z_1 and above and below the *Seminula* oolite in S_2. There is no sign of chert in the Sodbury, Tytherington and Wickwar sections. With regard to the Forest of Dean, Dr. Sibly informs me that he does not know any considerable development at any horizon anywhere in the district.

Chert occurs low down in Z along the S.E. margin of the South Wales coalfield and in the Gower area, where it is also found at three other levels—in S_1, in the Black Lias of lower D_3 (D_3x), and in the lagoon-phase rocks of upper D_3 (D_3p).

In the Pembroke and Tenby district Dixon[114] describes chert as occurring at many horizons of the Main Limestone (*i.e.* β to D_2), especially in rocks of the Zaphrentid phase, which form most of the sequence in the southern outcrop. Cherts are mentioned as occurring at the base of the Millstone Grit at Lydstep, Gower, and all along the north crop of the South Wales coalfield.

In the Midland[115] area there is a great development of nodular and lenticular chert in the thinly-bedded upper D_2 limestones. Feeble development may occur in the thickly-bedded D_1 limestones. The D_3 beds also contain abundant chert, while in Flint[116] the development of chert in the upper D_3 and lower Lancastrian (' Cefn-y-fedw sandstone ') is one of the most remarkable in the British Isles. These cherts are not of the

[112] *Geol. Mag.*, lix. (1922), p. 79.

[113] *Ibid.*, vol. lviii. (1921), pp. 265-78, and vol. lx. (1923), pp. 168-83.

[114] *Pembroke and Tenby Memoir*, p. 69.

[115] *Q.J.G.S.*, vol. lxiv. (1908), p. 38.

[116] See Sargent, *Geol. Mag.*, vol. lx. (1923), p. 168. Other references will be found here.

nodular type, but, as Mr. Wedd informs me, are a cherty silicification of silts and shales, sometimes accompanied by patches of chert, in calcareous sandstones. Beekitisation of fossils may also be a marked feature of the Flint development.

Chert occurs in the Pendleside limestone of Pendle Hill. In the Settle[117] district chert occurs in the upper part of the *Bryozoa* series (S_2) in the districts between the faults, and is typically developed in the *Orionastræa* bed (base of Yoredalian). In Wensleydale and other Yorkshire dales cherts are well developed at several levels in the upper Yoredalian, particularly just above the Undersett limestone.

In the North-west Province chert is not characteristic; Garwood[118] states that it is met with locally, especially in the higher part of D, but never in any great quantity. Replacement of fossils by beekite is not unusual at various horizons. Cherty limestones occur in the Botany Beds, the highest calcareous beds in the Avonian of the North-west Province. Chert occurs low in the series near the bottom of the Seventh limestone (upper S_2) in the Whitehaven[119] district, and again in D_2 in the upper part of the Fourth limestone.

Classification of Cherts.

The cherts alluded to in the above list fall into three groups, which practically correspond with the three phases of deposition of Vaughan's Winnipeg report.

(*a*) The irregular nodular chert often forming impersistent bands at various levels throughout the South-west Province, and in the D_2 beds of the Midlands and Yorkshire, is specially characteristic of the standard limestones.

(*b*) The great development of bedded cherts in D_3 of the Midlands and North Wales and in the Bishopston beds (' Black Lias ') of Gower is intermediate in character between those of groups (*a*) and (*c*), and is specially characteristic of the Zaphrentid and Cyathaxonid phase. The laminated cherts of Z_2 at Vallis, Somerset, should probably be placed here.

Note.—In alluding to these cherts as *bedded*, it is not intended to imply that they themselves show traces of bedding. They are lenticular or nodular cherts developed along the bedding planes. The *laminated* cherts mentioned below are those frequently alluded to as *banded* cherts, but the term laminated is substituted in view of the fact that the term banded has often been applied to concentrically zoned flints.

(*c*) The laminated cherts of the lagoon-phase deposits of Dixon are represented by those of the North Devon Culm, by those of the P beds (D_3p) of Gower, and by those at the base of the Millstone Grit of the Pembroke area. The deposits in which they occur belong to the third phase of Vaughan's table (*Modiola* and *Posidonomya* phases and other shallow-water deposits).

117 *Q.J.G.S.*, vol. lxxx. (1924), p. 206.
118 *Ibid.*, vol. lxviii. (1912), p. 551.
119 See Edmonds, *Geol. Mag.*, vol. lix. (1922), pp. 78 and 81.

The two chief problems which confront a student of the cherts in any area are to determine in the first place the source of the silica, and in the second place to obtain proof as to its period of origin, *i.e.* to ascertain whether its deposition was contemporaneous with that of the associated strata, or whether it was due to some process of replacement.

Note.—There are possibilities of confusion in the use of the term *contemporaneous.* It may be used (1) as implying direct deposition at the same time as the associated strata. Or it may be used (2) in a sense corresponding to that in which the term *contemporaneous dolomite* is used, implying that the chert was produced by a metasomatic change shortly after the formation of the limestone with which it is associated. To avoid confusion I propose to allude to cherts of type (1) as *contemporaneous* and those of type (2) as *penecontemporaneous.* The term *subsequent* may then be applied to cherts produced by a relatively late alteration, *i.e.* one taking place after the consolidation of the limestone.

Mr. Dixon points out (by letter) that proof as to the period of origin is clearest in the case of cherts associated with contemporaneous dolomite. The organisms are perfectly preserved in the chert but obliterated in the surrounding dolomite. Consequently chert formation preceded the bulk of the contemporaneous dolomitisation.

The problems both as to the source of the silica and as to the period of its formation have attracted much attention of recent years, especially in America, and have been discussed in considerable detail by Mr. H. C. Sargent[120] in his study of the cherts of the Midlands and North Flintshire. As regards the source of the silica, one view is that it has a directly organic origin, being derived from the tests of radiolaria,or perhaps in some cases of diatoms, and from the spicules of certain kinds of sponges. The other view regards the silica as directly deposited from solution in sea-water.

The three types of chert may be separately considered.

(*a*) The irregular nodular chert often forming impersistent bands is the prevalent type in the South-west Province, and is probably the most widely spread in general. I have found no radiolaria and few sponge spicules in a limited number of sections of this rock from the Bristol district. Hull and Hardman,[121] and also Renard,[122] referring probably to chert of this type, consider it to be a pseudomorph of gelatinous silica after limestone, and believe that the change took place when the strata were more or less plastic. In the Burrington section the chert is particularly developed in bands of *Lithostrotion*, and at Waterlip and Windsor Hill in the Mendips in highly crinoidal limestone. In each case I am convinced that the chert is due to replacement, and I do not see any reason to assume that the limestone was still plastic when this took place. I should therefore regard the chert as *subsequent* in the sense alluded to above. As far as I know, all workers on the limestone of the South-west Province agree as to the origin of the associated chert by replacement.

[120] *Geol. Mag.*, vol. lviii. (1921), p. 265, and vol. lx. (1923), p. 168.
[121] *Sci. Trans. Roy. Dublin Soc.*, vol. i. (1878), pp. 71-94.
[122] *Bull. Acad.Roy. de Bel i ue* 2me ser., t. 46, pp. 471-98.

Silicified foraminiferal limestones and oolitic cherts such as those from Bullslaughter Bay, Tenby, described by Dixon,[123] are obviously cases of replacement. The oolitic cherts, which are devoid of spicules, are lenticular intercalations in rocks of Zaphrentid phase, crowded with highly spicular cherts, so that the average sea-water which soaked them while they were still within its influence would probably carry some dissolved organic silica.

(*b*) We now come to the cherts occurring in bands or beds, sometimes tabular, more often nodular, at various levels and horizons. Such cherts are particularly characteristic of the D_3 beds of the Midlands and N. Wales, and the equivalent level of Pembrokeshire and of Gower ('Black Lias'); and whatever be the method of formation of the cherts of the Midlands and Flint, there can be no doubt that some of the Zaphrentid-phase cherts of S. Wales resemble the standard-phase cherts in being due to replacement. Of these rocks Dixon[124] remarks that doubtless in all cases they owe their silica largely to sponge spicules. Such spicules have been observed in sections of the chert from many localities, *e.g.* the 'Black Lias' of Gower, also Chirk, Holywell and Prestatyn[125] in Flint. G. J. Hinde[126] refers to the cherts of N. Wales as 'remarkable and hitherto unequalled sponge beds.'

The presence of the sponge spicules has hitherto been as a rule claimed as indicating the source of the associated chert. Sargent regards the matter from a different light, his argument being that, if solutions capable of dissolving organic silica were present to the extent necessitated by the sponge-spicule theory, it is hardly likely that any spicules would be preserved. This argument would, on the other hand, counter that adduced from the frequent absence of spicules in sections of Carboniferous cherts.

Mr. Sargent's opinion as regards the bedded cherts of the Midlands and Flint is that they are due to deposition contemporaneously with the country rock, and not, except to a limited extent, to any metasomatic replacement thereof. The source of the silica is found in the immense quantity which must be poured into the sea in solution in river-water.

(*c*) Evidence of the presence of organisms is generally very clear in the case of the laminated cherts of Dixon's lagoon-phase deposits. Thus the radiolarian character of the Codden Hill cherts of Barnstaple has long been familiar. Similar radiolarian cherts occur in the P beds (D_3p) of Gower. There can be little doubt that the silica of these deposits is largely, at any rate, derived from the associated organisms, and that the cherts are contemporaneous in the sense that they are not due to the subsequent introduction of silica. It cannot be denied, however, that the amount of silica present in these rocks is so much in excess of the radiolaria themselves as to suggest direct precipitation.

The chief facts relative to cherts may be summarised as follows:—

The origin of the silica is (1) organic, and derived from siliceous organisms (radiolaria, diatoms and sponges); (2) inorganic, and derived from the silica in solution in sea-water.

[123] *Pembroke and Tenby Memoir*, p. 70.
[124] *Ibid.*, p. 70.
[125] G. H. Morton, *Proc. Liverpool Biol. Soc.*, vol. i. (1887), p. 69.
[126] *Geol. Mag.*, Dec. iii., vol. iv. (1887), p. 444.

Although sections of many cherts disclose the presence of siliceous organisms, this is not generally the case, and although the absence of such organisms is by no means a conclusive argument against their former presence, yet it does not seem probable that they can have supplied the immense quantities of silica that are so often met with. Hence inorganic silica must sometimes be called on.

As regards the period of chert formation, the best case for contemporaneous direct deposition is that afforded by the laminated chert of group (*c*).

Penecontemporaneous cherts in the sense defined above are illustrated by those interbedded with contemporaneous dolomites, while the irregular nodular cherts of the South-west Province and many other areas (group *a*) are due to replacement and may sometimes be penecontemporaneous, but in many cases are probably subsequent. The same is probably the case with many of the cherts of group (*b*). Difference of opinion exists regarding the group (*b*) cherts of the Midlands and N. Wales, the bulk of which, according to Mr. Sargent, are due to contemporaneous deposition.

DETAILS CONCERNING VERTICAL SECTIONS.

The minimum of detail is introduced into the actual section. Unconformities and other breaks = U . . ., a = algal layer, c = coal, ch = chert, d = dolomite, m = Modiola-phase deposits, p = goniatite—lamellibranch or Culm phase, ps = pseudobreccia, x = Zaphrentid or Cyathaxonid phase.

1. **Bristol.**—Mainly from Vaughan. Post-Avonian not to scale.
2. **Devonshire.**—From table given by Evans, *Proc. Geol. Ass.*, vol. xxxiii. (1922), p. 205 (not to scale).
3. **Chepstow Area.**—From information supplied by Mr. W. W. Jervis.
4. **Forest of Dean.**—From Sibly, *Geol. Mag.*, 1912 and 1918, and from information supplied by him.
5. **North Crop of South Wales Coalfield.**—From the *Geological Survey Reports* and information supplied by Mr. T. N. George.
6. **Gower.**—Compiled from Dixon, *Q.J.G.S.*, 1911, p. 505. Thickness of the K beds from N.W. Gower, the remainder from E. Gower. In addition to that at the levels indicated, there is some dolomite throughout D, S, C and Z. Mr. Dixon informs me that the shales above D_3, classed as P in the Gower paper, are probably Lancastrian.
7. **South Pembroke.**—From Dixon, *Pembroke and Tenby Memoir.* Post-Avonian from Tenby area, *not* South Pembroke. In addition to the levels indicated there is some dolomite at intervals throughout D, S, C and Z.
8. **Anglesey** (principal region).—From thicknesses given by Greenly, *Anglesey Memoir.*
9. **Flint.**—From thicknesses given by Wedd, *Flint, &c., Memoir*, 1924.
10. **North Derbyshire.**—The Avonian from Sibly, *Q.J.G.S.*, 1908, the Lancastrian from information supplied by Mr. J. W. Jackson. S_2 also entered on the authority of Mr. Jackson.
11. **Clitheroe District.**—Adapted from Parkinson, *Q.J.G.S.*, vol. lxxxii. (1926), with additions from information supplied by him.
12. **Settle.**—Adapted from Garwood and Goodyear, *Q.J.G.S.*, vol. lxxx.
13. Yorkshire Dales (generalised).—From section drawn by Mr. R. G. S. Hudson.
14. **West Cumberland** (Whitehaven).—Mainly from Edmonds, *Geol. Mag.*, 1922. The upper beds chiefly from information supplied by Mr. Dixon.
15. **East Cumberland** (Alston).—Drawn up by Dr. Stanley Smith from Westgarth Forster's section.
16. **South Northumberland.**—Drawn up by Dr. Stanley Smith from the *Northumberland Memoirs of the Geological Survey.*
17. **North Northumberland.**—Drawn up by Dr. Stanley Smith from the *Northumberland Memoirs of the Geological Survey.*

NOTE.—In sections 1, 3, 4, 6 and 7, the K beds succeed *upper* O.R.S. conformably; in section 5 an unconformable junction is indicated between K beds and *lower* O.R.S.

SECTION D.—ZOOLOGY.

BIOLOGY AND THE TRAINING OF THE CITIZEN.

ADDRESS BY

PROFESSOR J. GRAHAM KERR, F.R.S.,

PRESIDENT OF THE SECTION.

I PROPOSE in this address to depart somewhat from precedent, and to devote it neither to a general review of recent progress in our science, nor to the exposition of my own special views on problems of evolutionary morphology, but rather to a more general subject—one which I believe to be at the present time of transcendent importance to the future not merely of our nation but, indeed, of our civilisation—namely, the relation of Biology to the training of the future citizen. Speaking as I do from this chair, I need hardly say that by Biology I mean more especially Animal Biology.

It is unnecessary to emphasise at length the enormously important part which biological science plays in the life of our modern civilised State. The provision of food for the community—crop-raising, stock-breeding, the production of dairy products, fisheries, the preservation of food by canning and freezing, and so on—is obviously an immensely complicated system of applications of biological science. And so also with the maintenance of the health of the community—the prevention of disease, much of which is now known to be due to the machinations of parasitic microbes, often transported and spread by other living organisms, and the cure of disease by the modern developments of medicine and surgery—these again are applications of biological science. When we contemplate merely such simple facts known to everyone, when we see to what an extent the results of biological science are woven in and out through the whole complicated fabric of modern civilisation, when we contemplate further the gigantic expenditure in money devoted to the school training of our future citizens, it must surely strike us as an extraordinary fact that biological science enters hardly, if at all, into the school training of our average citizen.

What I have said, indeed, applies, if only in lesser degree, to the subordinate position occupied by science as a whole in our school training. In the early stages of human evolution, as we see illustrated on the earth of to-day by those comparatively primitive savages who still remain in the nomadic hunting phase, what we should now call science plays an all-important part in the education of the young individual: he is taught to observe accurately the phenomena of nature, dead and living, to draw the correct conclusions therefrom, and to regulate his actions accordingly. In our own early history science undoubtedly played an equally important

part in the training of the young. Even down into the Middle Ages it supplied an appreciable part of the curriculum of the educated man, the seven liberal arts of those days containing a large infusion of what we now call science. In later times, however, from the renaissance of classical learning onwards, science has been kept in the obscure background of our educational curriculum, and in spite of much tinkering of detail in recent years that curriculum continues unchanged in its main features: it remains preponderatingly literary and classical. Even to-day, if we listen to contemporary discussions on education, we commonly hear arguments as to the relative merits of different constituents of the current curriculum, but the general framework of that curriculum seems to be regarded as sacred from all interference.

And yet these recent years have witnessed the most tremendous advances in the evolution of our social organisation, and, as the position now is, it seems as certain as anything can be that unless further advance is accompanied by a corresponding evolution in the training of our future citizens a condition of instability will soon be reached such as to involve the risk of complete disaster. Probably the factor in our modern social evolution which has brought in its train the greatest danger is the development of what in general terms we may call means of intercommunication—the means by which transport is effected—on the one hand of material things, on the other hand of ideas. Primitive man in the hunting phase of his evolution is a nomad, but a nomad within a restricted area: his wanderings are limited by the more or less vague boundaries between his own territory and that of neighbouring tribes. He is entirely dependent for food and raiment upon what nature provides within these limits: he knows little of the world beyond except that it is peopled by strangers of varying degrees of hostility: his code of ethics is limited by the same boundaries—highly developed as regards intercourse with his own tribe, it ceases to exist in his intercourse with those outside. His dominating idea is loyalty to his own kinsfolk and fellow tribesmen, and for this idea he is ready to make any sacrifice.

With advancing evolution, when the communal unit is no longer the clan or tribe but the nation or federation of nations, geographical and political boundaries still exist; but with the evolution of means of transport by road and rail and sea they cease to form impassable barriers—men and goods are able to pass them freely. Of even greater moment to citizenship than the transport of material things is the transmission of ideas. The great developments in this have come about in the first place with the evolution of language, the vehicle of thought, which has rendered possible the transmission of thought from individual to individual. The use of visible material symbols of a lasting kind—whether pictorial or simply conventional, as in writing and printing—while facilitating still further the transmission of thought from individual to individual and from place to place, has done far more, for it has enabled the achievements of each generation to be handed on to its successors with a completeness that was quite impossible by the merely spoken word.

While these advances in the methods of transmitting thought have played an all-important part in rendering secure the orderly progress of human knowledge, they have brought in their train curiously one of the

most potent disturbing factors to the progress of communal evolution. This disturbance is brought about through interference with the workings of one of the great principles of communal evolution—that of leadership.

Leadership.

Already in the primitive tribal community we find this factor at work. Tribes differ in their size and power—their men may number a mere half-dozen or several hundreds—and the main factor in this is the personality of the tribal chief. Among his own men the chief stands out by his capacity, mental and physical: a quick and accurate observer, he is also quick and accurate in drawing his deductions: he is wise, he is rich in knowledge and in its bearings; while alert and quick in decision, he is of steady nerves, has a good sense of balance, and is reliable in emergency.

And so it is onwards through historical evolution—the chief, the ablest man of his tribe, finds his successors in a long sequence of natural leaders of men.

It is the more modern developments concerned with the transmission of thought—printing, telegraphy, wireless telephony, cinematography, and so on—that constitute the great disturbing factor, inasmuch as they have given enormously increased importance to elements of individual personality quite distinct from general strength and capacity, mental and physical. Amongst such elements there stand out conspicuously oratorical power and skill in the method of advocacy. The leader no longer forces himself to the front by the sheer power of his outstanding constructive ability; the place of this is to a great extent taken over by the power of effective and persuasive writing and speaking. The most responsible posts in the leadership of the modern State have been rendered accessible to the skilled orator, even though his constructive ability in statesmanship may not be of the highest. That this development involves serious dangers is obvious; it seems equally obvious that one of the main tasks confronting the community is the devising and setting up of the educational safeguards which alone can be efficient against these dangers. The task will, indeed, be no easy one: it will clearly, for its satisfactory accomplishment, call for the best intellects the community can provide. However great the ability of those to whom the task is entrusted, it will prove one of high complexity and much difficulty; but certain inevitable conclusions seem to be visible, one of the chief of these being the need of drastic cutting down of the number of subjects at present inflicted upon the young citizen in training during his school period. How exactly this is to be done will have to be carefully worked out; but it seems clear that at present an immense amount of time is given, during the early stages of the curriculum, to subjects which might profitably be replaced by others of greater value in mind-training during these earlier stages. If postponed to a later stage of mental development such subjects can be mastered in a small fraction of the time required in the earlier stages—when, by the way, their prolonged and wearisome study is but too apt to kill effectively all interest on the part of the pupil in the particular subject.

While I am in complete agreement with those who desire to see the school curriculum greatly lightened as regards number of subjects and who desire to see 'snippets of many subjects' replaced by more thorough

training in a few, my special task now is to urge the necessity of including in the training of every citizen before the completion of his school period at least a grounding in the main principles of biological science.

It is necessary in approaching any such question to keep clear in our minds the two main functions of education: (1) the educative function in the strict sense—the training and development up to the highest attainable level of the brain-power which Nature has provided, and (2) the informative function—the providing the mind with an equipment of information which will be of use to it later on.

Science and the Curriculum.

It is again necessary to glance for a moment at the general question of science in relation to education. I, of course, believe that the almost complete exclusion of science from the elementary education of the young which has persisted over a prolonged period has been a real tragedy. In the life of the ordinary active citizen, as opposed to that of the mere scholar and recluse, some of the most important factors are those which training in science is specially adapted to develop. Such, above all, are the powers of accurate and rapid observation, and of the accurate and rapid drawing of conclusions from observation.

But I do not support the claim of Biology to an important place in the basic stage of school education, which should have to do with the early development of these powers. On the contrary, I harbour no doubt in my mind that the department of science to be used for this purpose is not Biology but Physical Science. For the early training of the powers of observation there are two essentials: (1) that the phenomena observed should be capable of numerical expression to a high degree of accuracy, or, in other words, that they should be measurable; and (2) that a given observation should be capable of repetition over and over again under approximately the same set of conditions. Biological observation fails as regards both of these essentials. When we proceed to apply the method of measurement to something that is alive or that has once been alive, or to some form of vital activity, we find ourselves confronted not with a phenomenon of comparative simplicity, but with a complex of extreme and, in great part, unknown intricacy. If we measure the length of marks upon a piece of paper, or of similar rods of a particular metal, we obtain by so doing data of a totally different order of scientific reliability from those that we obtain by measuring the length of some particular animal, where the particular dimension is the visible residuum left at the end of an immense chain of events during the racial and the individual history of the animal. While such measurements may provide important material for the skilled biometrician, they are, as I believe, totally unsuited for use in elementary education. And a somewhat similar consideration affects the *repetition* of observations upon living things or upon things that have lived—the observable phenomena result from the interaction of so many imperfectly known factors, and are so liable to the influence of disturbing forces, that it is difficult or impossible to repeat observations with any assurance that all the conditioning factors are really the same.

It is rather in the later stage of education—the informative stage—when the individual has already had his powers of observation and

reasoning developed in the earlier stages, that Biology should be called upon to play its rôle.

What is required is by no means the storing of the memory with a vast array of separate facts. It is rather that the budding citizen should be given a grasp of broad principles, as accepted by the competent authorities of the day. Such broad principles are generalisations from immense masses of detail. The probable soundness of the generalisation is intimately related to the broadness of its basis of fact. It is, of course, impracticable to place before the pupil the entire body of facts that constitute this base, and if it were possible it would be useless, for it is only a master who is able to perceive clearly the relations of superstructure to base. The object of the teacher is, then, not to attempt the vain task of demonstrating the truth of the general principle in the short period available: such facts as are introduced should serve merely to illustrate the particular principle and facilitate its appreciation.

I know that there are many who will criticise as unscientific and unsatisfactory such a simple manner of approach to general principles. They will say you cannot really instil such principles unless you make the pupil go through an elaborate course of laboratory training in dissection and microscopic observation such as we impose upon the specialist student of Biology. I do not agree. My experience has been that an audience, whether of youths or of adults, of ordinary average composition such as we get in a public lecture in a big industrial city, appreciates the points and follows the argument perfectly satisfactorily without such elaborate preparation, provided always that the argument is clothed in plain, non-technical English.

Biology in the Curriculum.

The question may now be put: What exactly are the biological facts and principles that should be introduced into such a course of instruction?

I. Firstly, the great fact of evolution. We still see with tiresome frequency in magazine articles the statement that evolution is not a fact, but merely an unproved hypothesis. No doubt it may be said with perfect accuracy that in one sense absolute proof is unknown to science, except in relation to successive steps of an operation in pure mathematics. Taking, however, the word 'proved' as we use it in ordinary life, *e.g.* in relation to a matter inquired into by a Court of Law, then we are completely justified by the data of embryology and palæontology in stating that evolution is a definitely proved fact. The realisation that it is a fact admitted by all competent judges should be incorporated in the mental equipment of every citizen at an early stage of his training.

II. Secondly, the broad fact of inheritance: the fact that the offspring repeat the characters of the parent—physical, mental, moral—but that this repetition is never so complete as to amount to identity as regards such characters. It is not always realised that, were the repetition actually exact and complete, it would constitute a fact that would shake our whole biological philosophy to its foundations!

The voyager upon the open ocean often sees a towering wave approaching his vessel, overwhelmingly impressive in its seeming individuality, and yet we know from physics that that onwardly rushing

wave is merely an apparent form, its outward semblance cloaking a comparatively gentle heave of the constantly changing particles of water. Or, again, one sees a cap of cloud covering a distant mountain peak. It seems to remain unchanged for hours, and yet we know it is undergoing constant change—water particles separating off on its leeward, and others being added on its windward, side. So it is with every mass of living substance: active interchange of substance—regarding much of the details of which we are profoundly ignorant—is constantly taking place not only between different parts of itself, but also between itself and its environment. It is this swirl of activity that constitutes life, and it carries with it the necessary implication that a bit of living substance is never the same at two separate instants of time, nor two separate bits of living substance ever identical in detail with one another. As soon might we think of constancy in a flickering candle-flame as in substance that is alive. And how, in view of this lack of constancy in all that lives, could we expect the progeny to be exact repetitions of the parent? How could we expect them to be otherwise than different from one another? If I would emphasise this point, commonplace though it will seem to many, it is because of the widespread tendency to ignore it even amongst biologists themselves.

The biologist constantly using the species as his classificatory unit involuntarily becomes dominated by his mental picture of the ideal member of the species, conforming exactly to description, and an individual which obviously does not so conform impresses him as a departure from his ideal. He comes in this way to think of variation as being an active positive process by itself, instead of an inherent characteristic of life and of inheritance. It would not occur to him to decry the science of physiology because it does not know the ultimate nature of the phenomena of life with which it deals, but yet he will sometimes attempt to discredit our evolutionary philosophy because it is similarly without any clear idea as to the ultimate nature and cause of the variation which is the necessary accompaniment of life.

This instability of living things which finds its expression in the constantly fluctuating incompleteness of inheritance has to be driven well home—in the first place because it constitutes the raw material of evolutionary progress, and in the second place because its proper appreciation provides the citizen with his surest safeguard against the talk of those who make it their business to belittle, if not to deny, the ever-present differences in the capacities of their fellow-men.

III. Thirdly and lastly, the fact of the struggle for existence in nature and the consequent elimination of the less fit. To the biologist and, indeed, to anyone who devotes thought to the matter, the struggle for existence and the consequent elimination of the unfit is an obvious truism, apart altogether from the question whether or not he accepts the Darwinian view of its potency as a factor causing evolutionary change; but yet among our fellow-citizens interested in sociological questions there is a very prevalent lack of appreciation of the widespread nature and the intensity of the struggle, induced in many cases by the perusal of charming descriptions of mutual aid in the animal kingdom, combined with ignorance of the fact that such mutual aid is restricted to the

individuals of a community, and is actually an important factor in rendering the community efficient in holding its own in the struggle with other communities.

When once the pupil has fully grasped the three great primary facts I have mentioned, he can profitably pass on to elementary notions of the biology of communal life. Gateways leading to these may be found by way of the fascinating phenomena presented by communities of social insects such as bees and ants and termites. Still better in some ways is the study of cell-communities, culminating in the immensely complex cell-communities that constitute the bodies of the higher animals. By whichever route, the pupil is easily led to the three great principles of communal evolution: (1) increase in the size of the community, (2) increased specialisation of its constituent individuals, (3) increased perfection of the organisation by which the constituent individuals are knit together into the communal individuality of a higher order. In some animal communities this organisation is of a material kind, the individuals being linked together by strands of living substance, in others the connection is not material but is of the nature of social interrelationships.

When once these basic principles are clearly apprehended an approach may profitably be made to the study of human society, where the same principles are seen clearly at work—the simple nomadic group with its individuals few in number, showing hardly any trace of specialisation, and so loosely knit together that they separate from one another under stress of circumstances, such as attack by a hostile tribe—leading up to the complex modern civilised State with its millions of inhabitants, intensely specialised for the performance of the various communal functions, and knit together by an immensely complex social organisation.

The Intercommunal Struggle.

The appreciation of the fact that our civilised community has come about by a long process of social evolution paves the way to an appreciation of the further fact that human societies are still in process of evolution—States becoming larger and larger, the specialisation of their citizens becoming ever more pronounced, their social organisation more complicated—and that here again a great driving force is the struggle for existence, in this case an intercommunal struggle.

It is surely one of the saddest experiences a biologist can have, to live amongst men whose communal evolution has lagged behind, and to see how, unless helped in their struggle with competitors at a higher level of social evolution by some natural protective feature such as geographical isolation or immunity to local diseases, they are doomed to disappear. Innumerable examples of this are seen in the continents of the New World, where the relatively primitive communities of red men have been displaced by whites in a higher stage of communal evolution. The same process has taken place in the past, races that lagged behind in their communal evolution giving place to others more progressive.

The realisation of the importance of intercommunal and interracial competition is of use indirectly as a safeguard against falling into the common error of ignoring differences—in material interests, in racial prejudices, in religious beliefs—those troublesome factors which, in actual

practice, form serious obstacles in the way of those who would find in signed agreements between different nations a sure shield against the danger of war.

The Biological Outlook.

Finally, our training, if successful in inducing in our citizen's mind what we may call the 'biological outlook,' enables him to take a fresh and an enlightening view even of that distressful subject, economics. He appreciates more fully how the customary units of the economist, pounds and dollars, are merely tokens with local values dependent on their power of purchase. In a remote spot on the earth's surface, a pile of golden coins becomes merely so much workable material out of which articles useful or ornamental may be fashioned; a bundle of scrip becomes material of possible use for kindling a fire. Their actual value bears no relation whatever to their token value in other circumstances.

Our citizen from his biological view-point looks beyond this veil of make-believe and realises that the true unit of value is the capacity of the human individual. He sees in each individual a biological capitalist. His store of capital may be small or large. It may consist of the precious bullion, intellectual power, or the humbler metal, bodily strength. And the store, small or great as it was to begin with, may have been simply left like talents buried in the earth, or by education it may have been increased in amount and coined into the kind of currency, such as skill in handicraft or other form of social activity, which gives it its greatest local value in the community.

To what End?

But now the question may fairly be put: what good would come of it all were the biologist given his way, and his subject, resting on a basis of elementary physical science, accorded the place in the ordinary school curriculum that he claims for it? How might it fairly be expected to work out in practice to the advantage of the community and of the individual citizen?

To state adequately the answer to this question would exhaust the time not merely of one address but of many, and I can only indicate one or two points which the answer would include. The scientific training we are arguing for would in the first place be a potent power on the side of social stability, inasmuch as it would help to develop the scientific habit of mind with its constant distrust of the ably stated 'case.' There is no more potent defence against the plausible rhetoric of the advocate than infusion of the scientific habit of bringing verbal statements up against the touchstone of actual fact.

With recognition of the principle that the welfare and happiness of the individual citizen is by no means independent of the material prosperity of the community, proper appreciation would be given to biological economics. It would be recognised that the training of the individual citizen must include the scrutiny of the nature and amount of his biological capital, and the taking of appropriate measures to increase his stock and to ensure its being minted into the most suitable form of currency.

Individual scrutiny would in turn drive home the necessity of confining within as narrow limits as possible the workings of the principle of mass

production in education. The application of that principle plays a great part in industry, but its introduction into the sphere of education is apt to be accompanied by forgetfulness that its success in industry is entirely conditioned by one basic factor, namely, uniformity of raw material. Without such uniformity the practice of mass production is recognised as absurd. The clearer realisation how completely wanting this uniformity is in the human raw material on which education works will serve to impress upon us all the desirability of confining mass education within the narrow limits at the commencement of the educational period when it is for practical reasons unavoidable.

The fostering of the biological element in education would do something to quicken into renewed life the primitive relationship of parent and offspring which has tended to become deadened under the influence of modern civilisation and more especially of mass education. The parent would be no longer encouraged to regard his child as merely number so-and-so in a vast number of units poured into the hopper of the educational mill. He would be encouraged to keep up his natural sense of responsibility for the welfare and interests of his offspring—the slackening of which in our present system is responsible for so much that is deplorable—and incidentally he would be stimulated to take a live interest in the education of his children, in the selection of those responsible for the ordering of that education, and in the subject of education as a whole.

This greater interest would lead him to a better appreciation of many things connected with education. One of those of which a deeper appreciation is greatly needed has to do with the reciprocal relations of physical and mental deportment. Passing along a city street the biologist is constantly having his attention caught by little peculiarities of attitude and movement which reveal to him the existence of peculiarities of quite another kind—stability or instability of character, mental sluggishness or alertness. He realises to the full that there is a reciprocal relation between mind and body. With the spread of the biological outlook through the community this realisation would become general, and we should have the average parent awakening to the full appreciation of the fact that he is inflicting grievous harm upon his children if he fails to see to it that their ordinary education is accompanied by the full allowance of physical training and games, which, while developing physical activity in the first place, plays a great part in developing mental alertness as well.

The training of the individual to the highest attainable degree of biological aptitude as a citizen involves naturally his relations to other members of the community. He must be fit not merely to play his part as an isolated individual, but also to carry out smoothly and efficiently his communal activities. As communal evolution progresses, these latter relations become relatively more and more important. In the primitive savage phase the individual is still subject to the ruthless pressure of natural selection. His whole organisation—his bodily health and strength, the acuity of his senses, his mental alertness—is kept up to the highest pitch. As communal evolution goes on, however, the pressure of natural selection becomes modified. In one particular respect no doubt it becomes intensified, for the crowded community provides greatly increased

liability to the attacks of pathogenic microbes, and consequently we find active evolution proceeding in the direction of increased immunity to such as are prevalent and dangerous. It is a hideous experience to witness the immigration of people from a more highly evolved society with their accompanying microbes into the midst of a remote and primitive community, and to see the horrible ravages these microbes produce when disseminated amongst the virgin population. While, however, in this particular respect evolution proceeds actively in the more advanced communities, it is not so in other respects. The individual no longer depends on his perfect bodily fitness, on the acuity of his senses, on the alertness of his mind, to survive and reproduce. As a result, as seems beyond question, the individual necessarily deteriorates with high civilisation in his all-round fitness both mental and physical, and this retrogression renders him correspondingly more and more dependent upon the community for his welfare. Emerging from this consideration, we have the conclusion that with higher and higher communal evolution, with more and more intimate dependence of the individual upon the community, we should have greater and greater attention paid in our educational system to these subjects which have to do with the citizen's relations to and duties towards the community—such as discipline, ethics, patriotism and loyalty to country and comrades, and the past history of the community and race.

The last of these, in fact, the history of our race, is one of the subjects of the present school curriculum which the biologist would be particularly anxious to see retained, and even accorded increased importance. His natural sympathies go out to it, for his own philosophy—Evolution—is but history of a larger growth. No doubt he would sometimes wish its teaching to be modified in detail: he would like to have less attention devoted to brawls and murders—on however great a scale—and to have a little space spared for the achievements of science. In my own town of Glasgow I often wonder how much the average child is taught regarding the two great events of the world's history which took place in that city—James Watt's improvement of the steam-engine and Joseph Lister's inauguration of antiseptic surgery.

In these flippant days there is a tendency to scoff at pompous lines regarding 'lives of great men,' and so on; but are we quite sure that our children are not greatly the losers by hearing so little in their school days regarding the dedicated lives of great heroes of science like Darwin or Lister?

In this address, which I must now draw to its close, I have touched upon some of the general considerations which naturally come to the mind of the biologist when he thinks of his subject in relation to this great and, as it has become, vitally important problem of the training of the future citizen. Some matters that at once suggest themselves I have deliberately avoided: Eugenics—there are others who speak of that; Sex—the whole air is abuzz with discussions on sex. The importance of every citizen being given a little elementary knowledge of the biological aspects of health and disease; the importance of the school paying more attention than it generally does to training the power of prolonged and concentrated effort upon dull bits of work: neither of these points requires any special emphasis.

There are, however, many other aspects of the problem which I refrain

from developing, only because forbidden by the tyrant Time. Summing up the more important of these, I would say that the biologist would like to see a movement of our whole educational system away from the merely literary, doctrinaire, academic regions, in which it is apt to be out of touch with the reality of biological fact and practical affairs. He would like to see a far more general recognition of the fact that the primary object of education is to make the individual able rather than learned. A learned individual may be, and often is, a stupid one. And in any case the development and the training of general brain-power fits biologically into the earlier years of life in a way that is not the case with the acquirement of mere learning.

He would regard as another prime object in the training of the citizen the getting him back towards the primitive habit of thinking constantly. The primitive savage is kept constantly alert by ever-present danger. He is constantly thinking about the meaning of what he sees and hears. Civilised man, freed from the stress of savage life, gets into the habit of not thinking. His actions become automatic. He gulps down whatever is served up to him. If he were only to think he would promptly discriminate as to what is worthy of acceptance and what is not.

The biologist would like to see still another reawakening of ancient custom, namely, the more effective shackling of personal liberty in the bonds of duty towards the community. Amongst primitive men one finds a high degree of personal freedom, but this is bounded strictly by the interests of the community. These interests are regarded as sacred, and the offender against them receives prompt and severe punishment. Throughout the long ages of social evolution, the traitor—the blackleg to his country—has ever been regarded as the most despicable of men, and it is a new and strange development of modern times that toleration is extended to those who deliberately work an injury to their country and kindred—it may be on the grounds of their own material interest. A biologically educated community, while according to the individual in his ordinary affairs the widest range of personal freedom, would take measures to prevent effectively its interference with the public welfare whatever might be the form of this interference.

There is one other argument I would use for the biological factor in training the citizen. As social evolution progresses, the natural differences between men become more and more marked, as does also the material expression of these differences. One individual—say, a Lister—is worth to the community many millions of pounds; another is worth little or nothing, or in some cases his value may be expressed by a negative quantity. And along with this increase of inequality there comes, unhappily, the deteriorating nervous balance which accentuates discontent and social friction.

The biological outlook I believe to furnish a most potent aid towards the smoothing away of such social difficulties and the lubrication of the social mechanism, for it enables us to see with clear vision through the obscuring veil of superficiality that separates class from class, and shows us how our fellow-citizens beyond, in spite of their differences in manners and clothes and language, are, after all, on the average, merely human beings like ourselves, fitted out with the same strengths and trammelled by the same weaknesses as our own.

SECTION E.—GEOGRAPHY.

THE ECONOMIC DEVELOPMENT OF TROPICAL AFRICA AND ITS EFFECT ON THE NATIVE POPULATION.

ADDRESS BY

THE HON. W. ORMSBY-GORE, M.P.,

PRESIDENT OF THE SECTION.

Four million square miles of Africa lie within the British Empire. In fact there is more of the British Empire in Africa than in any other continent. British North America and Australasia are both smaller in area than the African possessions of the Crown. Approximately three-quarters of this African area lie within the Tropics, and it is only outside the Tropics, in the Union of South Africa and Southern Rhodesia, that European colonisation has yet succeeded in establishing the European race in any considerable numbers.

I define Tropical Africa as that part of Africa which lies south of the Great Sahara and north of the Zambesi River. As far as the British Empire is concerned this area comprises three main blocks of territory: first, the East African group, consisting of British Somaliland, Kenya Colony, Uganda, Tanganyika Territory, Zanzibar, Nyasaland, and Northern Rhodesia. This block contains a population of approximately 12,500,000 Africans, 50,000 Asiatics, and less than 20,000 Europeans.

The second block, almost equal in area to the East African group, but with less than half the population, is formed by the Anglo-Egyptian Sudan.

In West Africa we have four colonies with a total area of half a million square miles and a population of over 24,000,000 Africans. In British West Africa there are no permanent European settlers or colonists, and owing to climatic reasons the European is only a temporary resident, usually for quite brief spells at a time. A small exception is found in the German plantations on Cameroon Mountain.

The greater part of these vast territories has only been brought under the guidance of British administration within the last forty years, consequently the problems of economic development as well as of policy and adminstration are comparatively new. . We are beginning to realise, however, that this new African Empire is one of enormous potentialities and great natural riches. These riches are in the main agricultural, as the mineral deposits so far discovered are comparatively few. History shows that the discovery of valuable minerals is one of the most fruitful causes of the rapid opening up of new country. There is copper, zinc, and lead in Northern Rhodesia; tin and coal in Nigeria; gold and manganese in the Gold Coast; but so far, at any rate, the value of these products is

comparatively small when compared with the value of the products of the soil and forests. For example, more than four-fifths of the exports of the Gold Coast are cocoa, and more than nine-tenths of those of Uganda are cotton.

The leading products of Nigeria and Sierra Leone are those of the oil-palm; those of Kenya and Tanganyika, sisal hemp and coffee. The principal export of Nyasaland is tobacco; of Uganda and the Sudan, cotton; and of the Gambia, groundnuts.

This brief review shows us we are considering countries to which the temperate world is looking to-day, and is bound to look more and more in the future, as the source of those raw materials and foodstuffs which cannot be grown in the temperate zones. They are thus of peculiar importance to Britain as a manufacturing country, but also to the whole civilised world inhabited by persons of European race.

Conversely the absence of iron and coal, as well as the character of the population, seem to point to Tropical Africa as an area of the world where manufacturing industry is not likely to develop. Consequently Tropical Africa is a natural new market for the manufactured goods of the temperate zones, and between Tropical Africa and the countries inhabited by Europeans there is a natural complementary trade between raw materials and foodstuffs of the one and manufactured goods of the other.

Thus we see that the development of the economic resources of Tropical Africa is one of our duties as well as one of our rights. We undertake the task from no selfish motive, but from the dual point of view of helping the indigenous populations to advance in the scale of civilisation and of furnishing the world with an increased supply of products which it urgently requires.

The task is complicated by two main factors: the first climate, and the second the wide differences in traditions and capacities between the ruling race and the native population.

As regards climate, we have to recognise that throughout practically the whole of the area with which we are dealing manual labour cannot be undertaken by Europeans. In many parts of the area the climate, and the dangers of disease which I include under the heading of climate, are such that even the task of supervision and leadership by Europeans is often rendered difficult.

There are in each of the five principal mainland territories of East Africa comparatively small areas in which the general altitude exceeds 5,000 ft. above sea-level, where this generalisation does not obtain. But even in these highland patches the European requires the assistance of native labour in any work of development which he undertakes.

So for the most part the rôle of the European in Tropical Africa, and especially in West Africa, is strictly confined within definable limits. The European in these areas is the administrator, the teacher—using the word in its broadest sense—and the organiser of trade and commerce. He is seldom, if ever, a direct producer.

Before the advent of European rule there was astonishingly little contact between Tropical Africa and the outside world. Africa was practically a sealed continent, both as regards knowledge and trade. But

to-day we are confronted by the impact of highly organised Western civilisation, with its immense command over natural forces by means of machinery, science and skill in the arts, on a people and a country in a far more primitive stage of development.

Perhaps nothing brings this out more clearly than the fact that, with the exception of a comparatively slight infiltration of the use of Arabic script from the north-eastern Sudan and from Zanzibar, we have found in Africa no knowledge of writing, and consequently no means of communication between man and man by means of the written word.

We still know astonishingly little regarding the history of the interior of the continent. We learn dimly the traditions of the continual movement of peoples, constant and almost universal warfare, of slavery and the slave trade. We must admit that the first contact between Europe and Tropical Africa was to take a hand in this last nefarious business, and up to a hundred years ago African trade and commerce may be summed up in the two words 'slaves' and 'ivory.'

It was only in the last decade of the nineteenth century and the first decade of the present century that the interior of Africa became effectively parcelled out among the principal European Powers. In some parts of it we are still in the pioneer stage, in others we are just passing out of the pioneer stage into a new stage of consolidation.

The history of modern Africa is bound up with the history of the railways which European enterprise is pushing every year into the interior of the continent. Forty years ago there were no railways in Tropical Africa. To-day there are over 10,000 miles, and the locomotive may be taken as the outstanding symbol of this new force which is entering into the continent for the first time.

One other fact is illustrative of our problem. Money is a new thing in Africa. I have visited a market town in Nigeria where I have seen cowrie-shells still being used as currency. Twenty-eight years ago the missionaries opened the first post-office in Uganda. British administration had not yet been established, and the missionaries produced their own postage-stamps, and the value on those stamps was expressed in cowrie-shells, not in pence. To-day something over £3,000,000 in coin and notes is being paid out annually to Uganda natives for their cotton crop alone. In West Africa money has only recently replaced square-shaped bottles of alleged gin and yards of cloth as the medium of exchange.

Money is therefore quite a new idea to the African mind, and it is even true to say of many parts of Africa that the idea that the products of the soil or of the forests have a value in the exchange is a new one. The 'economic crop' is really a new factor. The idea that land has a value is a new factor, particularly among the Bantu people of the continent, whose previous agricultural activities were limited to the production of a sufficient quantity of food by each family for that family and as tribute to a chief, while wives and cattle were regarded as the chief measure of a man's wealth.

The farther we push our investigations into the contrast between the old Africa of the past and the new just dawning, the more we have to realise how great is the gulf between them. In the old Africa, disease was regarded as the work of evil spirits, and the prevention and cure of maladies was

regarded, and is still so regarded in many places, as the task of propitiating these spirits. The European arrives and tells the native that these maladies are not caused by evil spirits but by mosquitoes and the tsetse fly! We must not be surprised if we were not believed.

I do not wish to draw an exaggerated picture, and the marvel is that the African native is accommodating himself so rapidly, and on the whole so cheerfully, to all this new world that has been brought into his midst.

It is, of course, a mistake to generalise about Africans as a whole, for there are probably just as great differences between the different races of Africa as there are between the different races of Europe, but generally speaking the African is probably the most imitative and adaptable of all races of the human family. He starts with a far cleaner slate than the populations of Asia with their ancient civilisations and intensely conservative traditions.

To the African the steam-engine is not so much a foreign devil as a new and wonderful toy. The African, too, has no idea of caste; he is ready to turn his hand to any trade or craft, and to try anything new. He is perhaps even too ready to jettison his old ideas and customs. The Mohammedan peoples of Northern Nigeria, the Sudan, and Somaliland are more conservative and more stable, but, for the rest, Africans are eager to adopt hurriedly European clothing and European ideas. The moment they acquire wealth they demand education, and the particular form of education which they seek most is what is described in West Africa as 'education for book.' The main source of attraction to the Missions is the Mission school.

It is true that the impact and sudden development of the African produce changes which are only skin-deep. This must necessarily be so where things are moving so rapidly. The mere fact that the African native so readily abandons his own primitive paganism for Christianity or Mohammedanism is an indication not that his conversion is ungenuine but that it is frequently not very profound. Reversions and breakdowns are inevitable. Remove the impetus and the example and the African will quickly slip back into old ways. The fact is that both the African himself and we ourselves are setting a very fast pace, and we must expect that the results of our efforts will be frequently superficial.

I have already said that we still know comparatively little about the history and mental traditions and aptitudes of the African native. The work of the anthropologists is yearly widening our knowledge. Anthropology is a science which is rapidly expanding in its scope. It is now recognised that it must include a study of native law and customs, methods of agriculture, beliefs, and languages. Their variety is infinite, and as we are still in the stage of collecting a vast mass of data there has as yet been little time or opportunity to develop adequately the comparative and synthetic side of the work; still less to be able to deduce from our knowledge those lessons which will be most useful in guiding policy. There are so many tribes, so many languages to be studied, and such a variety of local problems, that it is very difficult to ensure that scientific investigation shall keep pace with the practical day-to-day running of Government administration and of economic development. Consequently our methods and the whole character of our administrations in different parts of Africa

may seem to be empirical rather than to follow any clear line or consistent principles. We are always supposed to have a natural genius for empiricism, and probably our greatest successes in Colonial Administration are due to the fact that we are naturally suspicious of the doctrinaire, and are prepared to delegate authority to the individual on the spot. Nevertheless we must henceforth clear our ideas on certain fundamental questions which are common to our problem. We can begin to take stock, and judge of cause and effect on the basis of a great mass of ascertainable knowledge.

Perhaps the first problem which we should examine is what is the effect of the European impact and economic development on the numbers and health of the African population. Africa is a very sparsely populated continent. The group of our six East African dependencies has an area approximately equal to that of British India. Yet in East Africa we have a population of $12\frac{1}{2}$ millions, as against over 220 millions in British India. Even in British West Africa, which has double the population for half the area of East Africa, the population is still sparse. The following table of population densities is taken from the Report of the East Africa Commission :—

(1) Transkei (Cape Colony Native Reserve)	59 per square mile
(2) Nigeria	53 ,, ,,
(3) Gold Coast (Colony only)	50 ,, ,,
(4) Basutoland	42·5 ,, ,,
(5) Uganda	33 ,, ,,
(6) Nyasaland	31 ,, ,,
(7) Tanganyika Territory	11 ,, ,,
(8) Kenya Colony	11 ,, ,,
(9) Northern Rhodesia	3 ,, ,,

The population per square mile of

England is	701	Japan	339
Belgium	658	Italy	319
Germany	348	France	187

On the other hand, our African territories have a far denser population than our as yet undeveloped Dominions or the rapidly developing countries of South America. The population per square mile of

New Zealand is	11	Australia	2
Brazil	9	Canada	2
Argentine	8		

Naturally these all-inclusive figures do not give a complete picture of the distribution of population. For instance, in Nigeria the population of the great Province of Kano is over 100 to the square mile, while that of Bornu adjoining it is only 23 ! Broadly speaking, however, there is more fertile land in Tropical Africa than there are people to cultivate it, and in the development of Africa it is an axiom that with rare exceptions—such as British Nyasaland—the demand for labour always exceeds the supply. This shortage of available labour is already observable in connection with the native cultivation, as in the cocoa industry of the Gold Coast or the cotton industry of Uganda, quite as much as upon the European plantations of Kenya and Tanganyika.

An increase in the man power of Africa is everywhere required if its resources are to be developed by any means whatever, and it is very important to ascertain what effect European contact and economic expansion are having on the vital statistics of the various territories.

The trouble is that we have very little data to go upon. In regard to many of the territories the 1921 census was really the first one that can be taken as effectively reliable—and the absence of scientific statistics is one of our difficulties. It is only in the Union of South Africa, with its far longer history of established government, that we have sound figures for purposes of making deductions.

The Royal Society of South Africa has recently published an extremely valuable paper by Senator Alexander Roberts, entitled 'A Statistical Enquiry into the Population Problem in South Africa.' He proves that the rate of increase of both the European and native populations is astonishingly low and seems to be decreasing. Between 1904 and 1921 the white population of the Union has only increased by 1·87 per cent. per annum, whereas between 1835 and 1904 the annual average increase was nearer 5 per cent. A normal percentage increase such as one has the right to expect would seem to be at least three.

Similar results appear from his examination of the statistics of native population. Enumerations show a declining rate of increase everywhere except in Zululand. The native increase throughout the Union was about 2·4 per cent. at the commencement of this century. The figures for the famous Transkei native reserve, containing nearly one quarter of the total native population of the Union, are of special interest. Reliable data are available for that district from 1875 to 1921. The average rate of increase for the whole period is 2 per cent, but for the period 1911 to 1921 the rate has dwindled to ·68 per cent. per annum.

These figures are significant. They show that even in the healthiest part of the African continent, where modern hygiene and sanitary conditions are more developed, the native population, so far from tending to increase more rapidly, is increasing at an unexpectedly low rate, and that even the rate is diminishing.

When we turn to the more populous tropical areas of the continent we are faced by the fact that we have no scientific data to go upon. A great part of the area has only come under effective administration during the last thirty years. We have only the censuses of 1911 and 1921 to go upon. The 1911 censuses were admittedly far from perfect, and though the 1921 censuses marked a great improvement in accuracy, it is now generally admitted that in many places the enumeration involved estimating rather than actual counting.

There are very few places in Tropical Africa where it is yet possible to secure the recording of vital statistics. In the townships of Lagos and Freetown fairly accurate figures are obtainable, but nowhere else in West Africa. Thanks to the co-operation of the native administrations, useful figures are now obtainable in regard to several parts of the Uganda Protectorate, but elsewhere in East Africa the registration of births and deaths is as yet impracticable, and still more the causes of death.

From such figures as are available we can deduce the fact that in Uganda there can be little doubt that the population declined between

1900 and 1924. Such decline was due to two main causes. First, the great sleeping-sickness epidemic of 1902, which caused the death from this disease alone of 300,000 out of 3,000,000 in one year. The second cause of decline was undoubtedly venereal disease. This was particularly striking in the Principality of Bunyoro, where until active measures were undertaken by the British medical staff it was estimated that 90 per cent. of the population had become infected by syphilis. Thanks to the energy of the medical administration the tide has now turned, and during the last two years it would seem that there has been a slight increase—but very slight—in the population.

But, broadly speaking, in East and West Africa the principal cause arresting the natural growth of population is infantile mortality. It has been estimated that in the purely native district of Tanganyika Territory between Tabora and Lake Victoria there is an infantile mortality rate under the age of twelve months of anything up to 400 per 1,000. I was recently given the estimated figure of 250 per 1,000 in more than one part of West Africa.

The main cause of this very high mortality would seem to be malnutrition both of mothers and babies, and the continuance of barbarous superstitions in connection with childbirth and early rearing of children. Further, it must be remembered that in many parts of Africa it is the native custom that the women should perform a very large part of the agricultural work on the native holdings. This undoubtedly is affecting the infantile mortality, which has always been abnormally high.

The medical care of the natives, hygiene, sanitation, and preventive medicine are only just beginning to operate in many parts of Tropical Africa. In many places the natives first resort to the witch doctor or the old women, and only come to the European medical officer as the last resort.

It is not surprising, therefore, that in countries where infective diseases, many of them insect-borne, are rampant progress is slight. We must remember also that in many parts of Africa—South-Eastern Nigeria for example—the native methods of agriculture are still so primitive that the existing native diet is quite inadequate to provide the stamina necessary to withstand the attacks of disease. The great prevalence of septic ulcers is due partly to the unhygienic habits of the natives and partly to the low general health and resistance, due to malnutrition. The investigations now being undertaken by Dr. Fisher and others in Kenya into this problem of native diet are most important.

We must admit, however, that over and above these endemic causes the coming of settled rule and civilisation has aggravated the problem. Before we established roads and railways and suppressed the tribal wars, communities lived in comparative isolation. There was little trade or intercourse between neighbouring peoples. Now, however, the old barriers are broken down and natives travel all over Africa comparatively freely, with the result that they carry infection with them and diseases have far more opportunities of spreading than heretofore.

I think I have said enough to show what a vast task we have before us in increasing the number and well-being of populations for whom we have become trustees, and I now turn to some of the more important social problems that are arising as a result of rapid economic development.

How rapid this development is few people have yet realised. In 1921 the domestic exports of Nigeria were valued at $8\frac{1}{4}$ millions sterling, in 1925 at 17 millions. Those of the Gold Coast in 1921 were £6,000,000, in 1925 £10,500,000.

Such examples of expansion are sufficiently sensational, but the rate of development in West Africa is completely eclipsed by the rate of progress in East Africa. The domestic exports of Kenya and Uganda in 1921 were £2,250,000, and in 1925 £7,820,000. The corresponding figures for Tanganyika Territory are £1,000,000 in 1921 and £2,900,000 in 1925.

These figures are illustrative of the sudden acquisition of money wealth among peoples to whom in a very large measure such an experience is entirely novel, and there are not a few students of the problem who are inclined to think that the rate of progress is almost too fast.

However this may be, I doubt if we can stop it or should be justified in doing so. Practically the whole of this rapid increase in production is represented by agricultural products and only a fraction by minerals. The two most sensational examples of the expansion have been cocoa in the Gold Coast and cotton in Uganda. The exportation of cocoa from the Gold Coast rose from 7,000 tons in 1905 to 78,000 tons in 1915 and 220,000 tons (nearly half the world's total supply) in 1925.

Uganda exported 93,000 bales of cotton lint in the season 1923-24, and the past season's crop has exceeded 200,000 bales.

In both these cases the crops have been produced entirely by what is termed 'native production,' *i.e.* by the native working for himself on his own holding, or for native chiefs or other native employers of labour.

Apart from the great accretion of wealth to the native producers, the development of a permanent crop like cocoa has an important bearing upon the development of native ideas in regard to land tenure. In parts of Uganda where the chiefs are large landowners, a new relation between landlord and tenant and landlord and labourer is developing.

I should say that the main effect of this economic development due to the native production of money crops is the enhancement of the individual *vis-à-vis* his society. In the old Africa society was largely communal, the rights and functions of the individual being entirely subordinate to those of the tribe or the village. With personal wealth an individual becomes emancipated from the former limitations and controls, and his first instincts are to better himself and his family not only in the economic but also by using his wealth to better himself in the social and political spheres.

The nature and sanctions of tribal authority are undergoing rapid changes, due in part to these economic causes and in part to a more profound spiritual and moral change. In many parts of Africa the two principal sanctions behind the chief's authority were formerly military and religious. The chief was not only the tribal or national leader for purposes of defence and offence, but also the guardian of the national fetishes and the chief executive of native law and custom, which are bound up ultimately with religious sanction. Consequently the missionary in converting the individual native to an individualist religion such as

Christianity must inevitably sooner or later affect not only the sanctions behind native political authority, but also the whole moral order associated with that authority.

In the coast towns of West Africa, where European contact has been established for a longer period than elsewhere in Tropical Africa, we observe this decay in tribal authority and the development of the individual in its highest degree. A very large proportion of the population of these towns is completely de-tribalised and no longer bears any allegiance to a native authority.

Some people go even farther than that, and describe these individuals as 'denationalised.' That is to say, we are witnessing the rise of a new community of people who have thrown off all their ancestral traditions and are engaged in imitating Western civilisation as fast as they can. Certainly the demand for Western education, particularly Western literary education, creates a most formidable problem, and throws special responsibilities on Government and missionaries alike in providing the right type of education for the African with his special characteristics, still living in Africa but in a new and rapidly changing environment.

Hitherto we have been perhaps too easily content to give the African a mere veneer of the nineteenth-century English Board-school education, without studying the real needs of the people or the right methods of bringing out their innate capacity on modern scientific lines. This is why a great experiment like the Prince of Wales College, Achimota, in the Gold Coast, is fraught with so much interest not only for that Colony but for Africa as a whole.

There are so many disruptive tendencies at work in Africa to-day that constructive thinking is urgently needed if the African communities are not to be reduced by our impact to the condition of disorganised mobs drifting about without leadership and without any clear goal before them except the new desire to acquire personal wealth.

I turn now to another aspect of the problem. Both deliberately and also unconsciously we are teaching the African the mastery of new arts and crafts, new methods of agriculture, and in some cases entirely new methods of life. In Tropical Africa we are forced, by the difficulty and expense of running things like railways with European staffs unsuited to the climatic conditions, to develop the skill of the African. He is being trained to become an engine-driver, a fitter, a mechanic, a stone-mason and a carpenter. Every year he is being entrusted with the management of more and more complex machinery, and every year sees an increase in the number of quite highly skilled African industrial craftsmen. Our recent experience shows that the African can very readily acquire skill in the mechanical arts and is capable of becoming an industrial craftsman of quite a high order.

Thus we are training up a new African labour class of wage-earners, for the most part in the employ of the various Government Departments, but in West Africa also in the employ of the mining companies and in East Africa in the employ of the European farmer settlers.

In the old Africa wage labour was largely unknown. Compulsory labour for communal purposes was a fairly general rule, while in many places, particularly in West Africa and those parts of East Africa which

had become subject to Arab domination, slavery was general for nearly all labour purposes. We have suppressed slavery and regularised the amount of compulsory labour which may be performed for chiefs or Government, and prohibited the employment of forced labour for purposes of private gain. That such drastic changes in the customs of the continent have already produced great economic and social changes—in this case for the better—must be obvious.

Nevertheless the labour problem in Tropical Africa is a most important one. As I have already stated, there is a far greater demand for labour than supply. There is no unemployed problem such as we have in Great Britain. On the other hand, there is not the same necessity for the African native to work as there is for the European. In Africa nature is bountiful, and food can usually be easily and cheaply obtained. The climate is such that the cost of housing and of such clothing as may be required is comparatively insignificant. The wants of the ordinary African in his present stage of development are few, and therefore the incentives to effort are far less insistent than in temperate climates and more civilised conditions.

In the old Africa—especially Bantu Africa—a young man's life was very largely taken up by fighting, with the preparation for fighting, and with hunting the wild game. Now that tribal warfare has ceased there is a real danger that deterioration will set in unless the energies formerly expended upon fighting are diverted to honest toil. To allow the manhood of a race to remain dependent on the labour of its women-folk is bound to result in national decay. I see nothing wrong in encouraging the African to work either as a direct producer or as a wage-labourer. In fact, his advance in the scale of civilisation is bound up with his economic advance as a producer. Nevertheless it is our duty to ensure that such a new development is made consistent with the lessons of experience concerning the welfare of labour and the best relations between employer and employed.

A good deal of discussion is going on just now regarding the treatment of native labour engaged on capitalistic enterprise in the development of the continent. In Tropical Africa the Governments, notably the Railways and Public Works Departments, are by far the largest employers of African labour, and they set the standards. Then there is the wage-labour engaged in the mining industries and upon the farms of European and Asiatic settlers in East Africa, and on the larger native farms in parts of West Africa and in Uganda.

In the past year there have been published two very important reports dealing with this problem. The first is the 'Rapport de la Commission pour l'étude du problème de la main-d'œuvre au Congo Belge,' issued by the Government of the Belgian Congo in 1925; and the second is the report by Major G. Orde Browne, Senior Commissioner of Tanganyika Territory, on labour in that country, issued last month by H.M. Stationery Office as Colonial Paper No. 19 of 1926. The last named is the most interesting and objective study that has yet been made by an experienced British native administrator on this subject. It touches upon almost every aspect of the question. It reveals great diversities of practice, and Major Orde Browne's observations on the data which he has collected are of the highest value.

There are, of course, many varieties of labour engaged in work on the same plantation. There is often the nucleus of permanent labour—squatters, as they are often termed—who live permanently with their families on the estate. Then there are the contract labourers, recruited often from great distances, who work for six months or a year and return to their homes at the conclusion of their contracts. Thirdly, there is casual local labour—usually harvest labour—drawn spasmodically from the neighbourhood. Each category requires special investigation.

Without going deeply into these questions I should like to quote some of Major Orde Browne's conclusions.

He writes: 'The impact of the capitalistic system upon the African social organisation in Tanganyika has not the dangers that it would have elsewhere; the almost entire absence of any class earning a living by industrial crafts eliminates the tragedy of the gradual crushing of such a class by mechanicalised competition, and there is no fear of a duplication of the situation which has arisen from this cause in Indian industrial centres. The African is self-supporting through his own agriculture, and if he goes to work for wages it is primarily to secure money for hitherto unrealised needs or luxuries. The class sometimes termed "wage slaves"—*i.e.* people who are forced by economic pressure to work willy-nilly at some particular task—is non-existent in Tanganyika and likely to remain so.

'The introduction of non-native enterprise has conferred a real boon on the African, since it has tended to regulate and equalise the extreme fluctuations resulting from the success or failure of the harvest. Whereas in former years a bad season might entail literal starvation for great numbers, it is now largely mitigated by the possibility of work on a property that provides foods as well as money; while improved transport consequent upon economic development has also done much to ease the situation created by a bad harvest.

'In another direction the native benefits to a minor though still appreciable extent from work on a plantation, it secures him adequate food at a time when the natural improvidence of the African has possibly led to a shortage before the new crop is reaped. That this aspect is fully appreciated is proved by the flow of labourers seeking work during the hungry months; I have, in fact, frequently been told by natives that they were going to work because the food in the village was growing scarce. It is, indeed, quite possible that this feature will have a beneficial effect on the whole population in time, for there is no doubt that at present many tribes are definitely under-nourished towards the approach of the new harvest, not through any failure of the previous one, but because the thriftlessness of the African frequently leads to inadequate storage or excessive sales.

'The creation of large industrial centres with workers completely divorced from food production would be an entire innovation of very doubtful desirability; it appears most unlikely to occur. The African man, and still more the woman, is firmly attached to the soil, and the whole fabric of social organisation is based upon the right to cultivate; it thus seems probable that the native will always aim at having his own home among his own crops, whether in a distant village or as a "squatter" on an estate.'

I think it is quite clear that there are four main duties which we have to perform if we are to render the impact of European civilisation upon the African not only innocuous but in the long run beneficial to the latter's welfare. We have in the first place to concentrate upon the various problems summed up under the words 'public health.' We have in the second place to improve the standard and quality of the native as an agricultural producer both of food and economic crops. Thirdly, we have to provide for further transport facilities both to secure the wider marketing of African products and to secure that in the movement of labour there is not the same wastage as obtains at present. Fourthly, we have to educate the native in such a manner that, whether he is a direct producer or a wage-earner, he may advance in the scale of civilisation and assimilate such new moral controls as will fit him to withstand the dangers and make the best use of increasing wealth.

As regards the second point, I think we must recognise that throughout the greater part of Tropical Africa below the 5,000 feet altitude native production under the guidance of European agricultural officers is the only practicable policy. Where there are highlands—and it so happens that these highland areas are at present very sparsely populated by Africans—European colonisation can be introduced. Personally, I hold that this European colonisation, so far from being detrimental to the native, may be of the highest educative value. The European farmer and stock-owner introduces examples of more scientific development, and I think it is already clear from the experience of Kenya that no small proportion of the natives who have worked on European plantations have learnt not only improved methods of cultivation which they can apply on their family holdings when they return to their reserves, but also something of a higher standard of life.

There are many plantations, particularly in Kenya, where an ever-increasing interest is being shown in the housing and sanitation of native labour. The settler's wife is frequently quite as valuable as her husband in educating up native labour not merely to be a more efficient labourer, but to be a better man.

The recent articles in 'The Times' from the pen of Mr. J. H. Oldham are among the most striking that have recently appeared upon native policy in Tropical Africa. He has clearly come to the conclusion that Kenya presents not merely a series of problems of local significance, but offers an almost unique opportunity for an experiment in racial co-operation, which, if wisely directed and based upon a scientific study of cause and effect, is perhaps more full of promise than any experiment that has hitherto been tried.

I think it is clear that in East Africa, where the contact between European and native is probably closer than elsewhere and the mutual interdependence most marked, we have an opportunity, such as seldom presents itself, for working out on scientific and humane lines the various contributions which European civilisation can give to the African races without destroying what is valuable and distinctive in their characteristics.

European colonisation, in the few areas where it is climatically feasible, has been the principal means of introducing not only a new crop but a whole series of new ideas which can contribute to the advance-

ment in the scale of civilisation of the peoples for whom we have become trustees. It is now generally accepted that throughout Tropical Africa we are in the position of trustees. In the words of Article 22 of the Covenant of the League, we are entrusted with the guidance of ' peoples not yet able to stand by themselves under the strenuous conditions of the modern world.'

The field of work covered by the phrase ' public health ' is a gigantic one, especially in Tropical Africa. In addition to certain diseases peculiar to the tropics, we find practically all the diseases common to temperate climates. Some of the latter appear to have been introduced as a result of European contact, and with regard to these it sometimes happens that, being new, there is no acquired resistance on the part of the populations affected. As an instance, I was told in my recent tour in West Africa that an African who gets tuberculosis rarely, if ever, recovers.

The special tropical diseases, such as malaria, sleeping-sickness, and the like, appear in both endemic and epidemic forms. It sometimes happens that an infectious disease will suddenly flare up and spread in tropical conditions with terrible results. The task of combating these epidemics is a gigantic one, and the field for research as well as treatment and cure is still large. I cannot overestimate the importance or value of research workers of all kinds in Africa.

I include in this field and in the field of ' public health ' the animal as well as human diseases. The scourges of rinderpest, pleuro-pneumonia, east-coast fever, red-water fever and trypanosomiasis require the services of an increasing number of veterinary research officers and veterinary staff throughout Tropical Africa.

We have been, so far, able to do little in the way of developing the immense potential resources of Tropical Africa in animal foods. I am told there are something like 6,000,000 head of cattle within 200 miles of the Uganda railway system, but at present there is no export of meat, and the first small shipment of East African butter reached England this summer.

In Northern Nigeria there are approximately 3,000,000 cattle cut off from the coast by a wide belt of tsetse-ridden country.

The development of animal husbandry is still in its infancy, as it is only in the European highlands of East Africa and among a few natives in Uganda and Tanganyika that the plough has been introduced. Elsewhere the land is cultivated by means of exclusively human labour with the hoe.

Finally there is transport. In many parts of Africa the principal means of transporting produce is still the human carrier. The human carrier is the most expensive and wasteful form of transport, as each individual is limited to an average load of approximately 60 lb., with a speed of 15 to 18 miles a day.

During my recent tour in West Africa I was at great pains to collect some figures regarding the comparative costs of different forms of transport. In the populous cotton-growing area round Zaria in Northern Nigeria head transport costs from 2*s.* 6*d.* to 3*s.* 6*d.* per ton-mile, motor transport 1*s.* per ton-mile, and animal transport 9*d.* per ton-mile, but the railway is carrying cotton and groundnuts at approximately 1½*d.* per ton-mile.

There can be no doubt that in the conditions of Tropical Africa, where roads are difficult to construct and even more difficult to maintain, the railway is by far the cheapest, as well as by far the most expeditious form of transport.

We are only at the beginning of the construction of our arterial system of railways. In the bulk of our African possessions such railways as do exist not only pay directly, but their indirect effect in bringing about production is sensational. When the railway from Baro to Kano was first constructed it was estimated that two trains a week would be all that would be required to carry the produce. When I was in Kano in February this year the average number of goods-trains leaving Kano was eight per day, and the tremendous expansion of the cultivation of groundnuts round Kano is due entirely to the coming of the railway. The export of groundnuts from Nigeria has risen from nil in 1910 to 120,000 tons last year. Similarly the expansion of cotton cultivation in Uganda is the direct outcome of the Uganda Railway and the feeder roads and water transport provided as auxiliaries to that railway.

Railways without roads are of little value, but I have definitely come to the conclusion that in the conditions of Tropical Africa roads are no substitute for railways. Tropical rains alone prevent the use of roads except during the dry seasons of the year.

Cheap transport is the life-blood of commerce, and everywhere I have been in Africa I have met the same demand by European and native alike for the provision of more roads and more railways. An example of the comparative stagnation of a naturally rich and populous country where the transport facilities are at present inadequate is provided by Nyasaland, where, in consequence of the incompleteness of Lake Nyasa's communication with the sea, some thousands of the most progressive natives leave the country every year in search of opportunity in more developed parts of Africa.

As in the other questions that I have discussed, the right solution of the many transport problems which arise in Africa can only be brought about by scientific study, and we should do well to watch all new developments in the means of transport, in new fuels and such-like matters which have a bearing upon any undertaking.

It is quite clear that we cannot develop either the land or the people unless we have easier and quicker means of access which modern rapid transport alone can give, but every line of railway we open, every road we construct, adds to the pressure of the impact of our coming, and I feel that, in addition to research into all these practical sciences, we shall require in ever-increasing degree the scientific observation of the sociological facts of our development ; mere humanity and enthusiasm is not sufficient. We have to study the problems we ourselves are creating with a considerable degree of objective detachment, and make certain that in our natural zeal for material development we are not disrupting more than we are creating. Here again it is Kenya that is leading the way, and the Kenya Government have asked that a portion of the loan to be spent on transport development in East Africa shall be ear-marked for the closer scientific study of what is rather loosely called ' the native problem.'

I think I have said enough to show that both our opportunities and

our responsibilities in our African Empire are very great. We can only solve our problems by applying to them the energies of our best brains, working in a spirit of objective detachment, studying failures and successes with a view to building up gradually a body of knowledge and experience which will render mistakes few and successes great. In this task we shall have to rely not only upon the continued efforts of those officials and unofficials who are actually working in Africa, but also on the men of science over a whole range of human experience such as are meeting under the auspices of the British Association.

There is no finer field for scientific investigation and endeavour than our tropical dependencies, and I should regard myself as fortunate if I were able on this occasion to arouse your interest in matters of great importance not only to the Empire but to the advancement of human welfare.

INHERITANCE AS AN ECONOMIC FACTOR.

ADDRESS BY

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PRESIDENT OF THE SECTION.

I. Introduction.

It will probably not be disputed that one of the fundamental institutions of our modern life which is likely to come under criticism and challenge in the next twenty or thirty years is that of Inheritance. In the first place, it is considered to be inextricably bound up with the inequality of incomes and wealth ; this inequality is said to be an offence against social justice ; and this offence, in turn, is said to be a source of social unrest which is against the interests of the whole community. In the second place, it is said to be essential to the accumulation of capital resources which, irrespective of their ownership, are said to be vital to progress, and, indeed, to the maintenance of industrial civilisation. In the third place, the satisfaction of fiscal needs, with the problems of the most suitable forms of taxation, raises important questions as to the economic reactions of inheritance. And lastly, the theory of socialism, continually urged as a better and more advanced system for economic life, is demanding profound changes in this principle.

It is the purpose of my address to ask whether economic science, standing clear of the political arena and so-called class interests, with their mere defence of what is, or their mere attack upon it, has had any definite findings to contribute to the discussion of the whole case ; and, if not, to suggest some of the chief questions which have to be explored and answered by economists before such findings can properly be arrived at, and to set out some possible or provisional answers which are at present available.

I am aware that a complete discussion of the matter extends beyond economics into ethical, and even philosophical fields. For example, suppose that a case of social injustice stands clearly proven upon all those facts of a case which are apparent to and comprehensible by the average individual who is moved by such a feeling. But suppose, also, that if an extension of mental power or experience were possible, a second series of underlying tendencies could be brought into comprehension which would modify that case, and correct an illusion. What is the proper mode of action ? If society has a right to determine its own form and destiny, must it be dealt with as it thinks it is, or as it *ought* to think it is ? It may well be that the full economic case will ultimately present the most difficult dilemma of all—a dilemma of two planes, transcendental, or, at

least, indeterminate. But my reflections upon the subject convince me that there is a field of deliberation and inquiry for economists which has, so far, only been casually and cursorily surveyed, but which must be carefully explored before the economic case can be presented.

II. Methods of Inquiry.

It has often and rightly been remarked that economics suffers as a science because it is unable to avail itself of the method of agreement and difference as an engine of discovery. The isolation of the presence of a particular factor, in order to discern if some effect or concomitant is always present; the isolation of its absence, to determine whether the supposed effect or concomitant is always absent; or, failing isolation, the association of that factor with a wide variety of others, and the observation of absence or presence of the antecedent with the presence or absence of the consequent; or again, the establishment of a quantitative relationship so that small and large ‘doses’ of the antecedent are accompanied by small and large doses respectively of the consequent: all these methods of direct experimentation open to the physical sciences are lacking to the economist. At the most he can follow by induction, with all the dangers of the false cause or the multiple cause, from observation of conditions existing at the same moment in different places, or at the same place at different times. If he is told that a given economic condition is brought about by a particular factor, such as a law or a social custom, he is seldom in a position to try the absence of that law or custom directly. Even if he does, the other conditions will not remain constant, and a logical weakness, if not a common-sense doubt, will exist. It will exist especially if some human likes or dislikes are involved, with consequent sectional feeling or sentiment. The precise economic effect of Prohibition, for example, is open to dispute because of the difficulty of dispassionate observation and reasoning where feelings as distinct from intellectual processes are involved.

But the economist has one advantage over the physicist. If the latter cannot actually remove the element in question from his phenomena or introduce it at will, he is usually at a loss. It is not generally open to him to *imagine* what would follow from its absence or presence, or to reason from analogy. (And here I am not overlooking the immense advances made by postulating, from observation of what are imagined to be effects, certain qualities which any factor, operating as a cause, would need to possess, and then elaborating what would follow from such qualities if they really existed, and finding, under other or different circumstances, that those prognostications are verified. Working hypotheses of this order are the commonplaces of science.) I am, rather, referring to another kind of postulation from experience. We see about us a certain set of economic conditions, and co-existent a certain law or custom. Interest or ignorance, or superficial observation, or political prejudice, may urge that they are related as cause and effect. But the economist has to be wary and watchful. It is open to him to imagine an economic world free from such a law or custom, and, by what he knows as to the behaviour of the average man under the hedonic impulse, to work out a new or hypothetical economic system. This type of economic psychology is rendered more possible if there are, in fact, already in existence a number

of individuals unaffected by the factor in question, whose behaviour is known and observed. By splitting the problem or the community up into its smaller significant or fractional sections, and making an estimate for each section, the possibility of error in the aggregated estimate is much reduced. If the resultant economic system which the economist deduces, following the subtraction or the addition of the particular custom or law, differs widely from the actual state, then the effect of that custom or law is obviously large and important. But if much the same state of affairs is hypothetically evolved, then the explanation of such a state must be elsewhere, if the explanation that is being sought is a true differential.

Everywhere we observe that men are not born equal; stations or fortunes in life are influenced by the fact that A and B were their parents, and not C and D. Something that A and B did or had, that C and D did not or had not, lives after them, and influences the economic position of X, the son of A and B, so that he is essentially different from Y, the son of C and D. The fact that men 'inherit' seems to be a fact that *prima facie* should have real economic significance. What would the economic world be like, as compared with the present economic world, if men really started equal? Or what would the economic world be like if men started with great inequalities, but these inequalities were quite fortuitous and had no relation to the circumstances or qualities of parents? In either case we postulate a world in which inheritance is absent as an economic factor.

It may well be that such an analysis would be inconclusive or indeterminate at the last, that at certain points we find we need close or exact statistical data that are absent, that at others the balance of probability as to economic psychology in the mass is in doubt, and that at a critical point unbiassed scientific estimates differ widely. At the worst we should know the area of scientific uncertainty; we should have exposed the points on which exact observation ought in future to be focussed; we should have given an estimated result with an idea of the probability of error. All of these stages are some way towards truth, at least further on than no analysis at all. In practical matters we may, after all, like others who have not joined in our analysis, have to 'jump' the gap and flagrantly guess, or act empirically by instinct. This the world has been doing on the widest scale for centuries while knowledge has been growing. But it is something to know that we are voting or deciding not indeed unscientifically but *non*-scientifically, which we have no business to do, save *faute de mieux*.

III. The General Heritage of an Environment formed under Certain Conditions of Inheritance.

I am not referring particularly to what we call *our social heritage*, *i.e.* to what the whole community A enjoys by reason of all that the preceding whole community B has left, either produced and evolved by B itself, or received and perpetuated by the whole community C that preceded B. I am dealing with the principles and fact of *individual* heritage. But the two cannot be wholly dissociated. As Prof. Pigou has said, 'environments have children as well as individuals.' And if the social heritage which A received from B was one in which individual heritage played an important part, it may well be that it is an entirely different social

heritage from what it would have been if the practice of individual inheritance in that heritage had then been absent. All men to-day are the heirs of a body of knowledge accessible to them without distinction; to a system of law, and to a considerable amount of communal wealth in parks, roads, and public facilities. That social heritage is an important factor in the total quantity of wealth which is produced in response to a specified aggregate of human effort to-day. If that heritage had been less in quantity or different in quality from what it actually is, the economic response to human effort to-day would certainly be quite different. It may also be, though this is less capable of proof, an important factor in the *share* of that quantity which accrues to a specified individual effort on the part of M and N, members of that community, respectively. Now the social heritage in question when it was 'incubating,' so to speak, in readiness for the present generation, was incubating under certain conditions of individual inheritance. Would it have been the same social heritage if the incubating conditions had not included individual inheritance?

It will be seen, therefore, that while we may focus on *individual* inheritance, it cannot be wholly dissociated from the communal aspects. When M comes into the world, he has, as an economic unit, to associate with two types of assistance, *i.e.* what he individually inherits from his parents, and what he socially inherits from previous society, and in both of these the principle of individual inheritance has been present.

But this social heritage, which is either economically richer or poorer in potentiality because it was the product of a set of conditions which included individual inheritance, is one of the chief working assets of every individual to-day, whether he has the benefit of some particular individual inheritance or not. The effects of inheritance as a custom do not, therefore, exhaust themselves in the direct line, as may be clearer from hypothetical illustrations. Suppose that the power of bequest is an immense stimulus to an able man, who under its influence exerts his ingenuity to the highest degree, creates new capital forms, and new mental embodiment of his genius in organisation. He raises the potentiality of the average worker as a unit in the social system, enriching himself and his social environment simultaneously. Under this system an individual in the next generation *observes* that he is not so well off as he would have been if the inherited wealth had not gone to the heir, but had been diffused over the community, but he perhaps fails to observe or realise that if the personal wealth had *not* been destined to go to the heir, the addition to the social heritage might never have come into being. He has not, indeed, inherited his share of the *whole* results of that man's life, but only that unseen, unrealised part which was enjoyed by the community. It was, moreover, impossible to inherit both, because this non-inheritance of the personal part was a condition under which *both* the personal part and the social part came into being. Whether this is a likely picture of reality or not depends obviously on the initial assumption, *i.e.* whether it is true in any sense that the power of bequest is a real differential as an economic incentive. Let us take an assumption applicable to the environment as distinct from the individual, and suppose that the knowledge that the individual can leave his wealth to his son and not to the community acts

as a social irritant, an economic 'sulkifier.' All workers' efforts are then crabbed and limited by their psychological state; their output is restricted, and often interrupted on trivial pretexts; they have no ready elasticity to participate willingly in new combinations of the organising mind. Then the total economic result of the community's efforts may be less than if our original mind had never exerted itself at all, producing individual wealth for individual bequest. The individual may, indeed, have abstracted, by his ingenuity, something as an accumulation for bequest, but the quantitative reaction on the economic or environment heritage is, in minute individual amounts, greater in the aggregate. The social heritage for the forthcoming generation to work with is poorer. Even if the lucky inheritor comes into his personal share he may have to employ it with an impoverished social heritage which will reduce his share far below what he, a man of ability, might have secured with a responsive social environment and a better social heritage. And each individual of that second generation has a poorer standard because of the stunted social heritage, poorer perhaps even if he had his share of the direct inheritance as a set-off. Here the truth of the conclusions is not objectively measurable, and depends on the truth of the assumption that the system is an economic irritant. Whether the system is an individual incentive or a social irritant, or both, or neither, is a question of average psychology. If both assumptions are true, the effects may balance, and the resultant economic systems, with or without the inheritance factor, be identical. But if either is more powerful the result must be different, and a system including inheritance either worse or better than the system without it.

I have laboured all this preliminary analysis, because it is so necessary to observe that the social and individual interact; so necessary to convince people that the dynamic tendencies of forces affecting the distribution of wealth are at least as important as the static results, and may even be more powerful.

IV. Contributions by Classical Economists.

The discussion by economists has usually arisen in connection with 'social justice' in distribution, or justice and expediency in connection with taxation. I will take two examples:—

In 1795 Jeremy Bentham asked the question, 'What is that mode of supply of which the twentieth part is a tax, and that a heavy one, while the whole would be no tax and would not be felt by anybody?' His plan was to abolish intestacy, all property where there was no will going to the State. He also proposed to limit the power of bequests of testators who had no direct heirs, and, in addition, that the State should have a half-share of sums going, either under a will or not, to such relatives as grandparents, uncles and aunts, and perhaps nephews and nieces, and also a reversionary interest in the succession of direct heirs who had no children and no prospects of them. I am not concerned to give you all the various legal and philosophical reasons underlying Bentham's proposal. He held that this was not a tax, and that its chief advantage was freedom from oppressiveness. In the case of a tax on successions, a man looks on the whole of what is left to him as his own, of which he is then called upon to give up something. But if, under the law regulating successions,

he knows that nothing, or only a small share, is due to him, then Bentham claimed that he would feel no hardship, 'for hardship depends on disappointment, disappointment upon expectation, and if the law of succession leaves him nothing, he will not expect anything.'

Prof. Seligman remarks that, exaggerated as Bentham's idea and distinction undoubtedly was, it contained a kernel of truth—namely, that there is no such thing as a natural right of inheritance, and that the extension of intestate succession to collateral relatives is, under existing social conditions, defensible only to a very limited extent. Graduation of the tax according to the degree of relationship was the definite corollary of his ideas. The idea of the basis of taxation described as the theory of copartnership originated later, when writers combined with Bentham's argument the thought that the State should inherit property from individuals because of what it does for them during their lives.[1] Andrew Carnegie, the millionaire, was an enthusiastic advocate of this idea. I am not concerned with the socialist or 'diffusion of wealth' theory, based upon the doctrine that it is a proper function of Government to use the power of taxation as an engine of social improvement, to stop the growth of large fortunes and bring about an equal distribution of wealth. Here it is necessary to remark that those defences of inheritance which rest upon the family theory of property are not altogether consistent with that kind of freedom of bequest which is commonly found in English-speaking countries. In Continental Europe, of course, the 'légitime,' and in the United States some of the State laws providing for a certain portion of the estate to go, in a definite direction, to near relatives, make for a better support of the family theory. Seligman says that most thinkers, as well as the mass of the public, would still to-day maintain the custom of inheritance, not, indeed, as a natural right or necessary constituent in theory of private property, but as an institution that is, on the whole, socially desirable. Those who are not prepared to accept socialistic methods of reasoning cannot acknowledge the validity of the 'diffusion of wealth' argument.

Other economists have discussed the question almost entirely as one of 'social justice,' and in so doing have often begged the question of its economic effects without examination.

John Stuart Mill held the view that there was nothing implied in property 'but the right of each to his own faculties, to what he could produce by them and to whatever he could get for them in a fair market, together with his right to give this to any other person that he chooses, and the right of that other person to receive and enjoy it.' He thought that it followed that, although the right of bequest or gift after death formed part of the idea of property, the right of inheritance, as distinguished from bequest, did not. The succession, in the absence of disposition, by children or near relatives, might be a proper arrangement, but he agreed that there were many other considerations besides those of political economy which entered into it. He traced in antiquity a definite economic factor, where the disposition of the property otherwise than to the family surrounding it and interested in it had the effect of breaking up a little commonwealth, united by ideas, interests, and habits, and casting them

[1] *Vide* Max West: *The Inheritance Tax.*

adrift upon the world. This created the idea of an inherent right in children to the possessions of their ancestors. But bequests at random were seldom recognised. Other reasons have usually been assigned by later writers, such, for example, as the supposition that the State in disposing of property along recognised lines would be likely to do it in a better way than the proprietor would have done, if he had done anything at all. Such reasons were hardly economic in their basis. Mill argued his case almost entirely on ethical and moral considerations, and not from the point of view of any greater economic advantage, either to the individual or the community. He reached more economic ground when he discussed the conflict that may exist between bequests and the permanent interests of the community. He says: ' No doubt persons have occasionally exerted themselves more strenuously to acquire a fortune from the hope of founding a family in perpetuity. But the mischiefs to Society of such perpetuities outweigh the value of this incentive to exertion, and the incentives in the case of those who have the opportunity for making large fortunes are strong enough without it.' [2] By this, he would appear to imply that economic expansion or betterment in one direction was more than offset by *economic* contraction or worsement in another, although one is never quite clear whether he is balancing against improved material welfare deficiencies in other kinds of welfare.

Of the French law he remarked that ' the extreme restriction in the power of bequest was adopted as a democratic expedient to break down the custom of primogeniture and counteract the tendency of inherited property to collect in large masses. I agree in thinking these are greatly desirable, but the means used are not, I think, the most judicious.'

When Mill comes to his case for limitation of bequests, he touches somewhat lightly several economic considerations—*e.g.* where capital is employed by the owner himself, there are strong grounds for leaving it to him to say which one person of those who succeed him is the best equipped to manage it and avoid the inconveniences of the French law of breaking up a manufacturing or commercial establishment at the death of its chief. He refers to the upkeep of ancestral mansions. He regards it as advantageous that, while enormous fortunes are no longer retransmitted, there would be, by the limitation, a great multitude of persons ' in easy circumstances,' for from this class the community draws benefits which are semi-economic or non-economic. Moreover, the practice in the United States, neither compulsory partition nor a custom of entail and primogeniture, allows for liberty to share wealth between kindred and the public, leading to munificent bequests for public purposes.

I will refer later to those other economic considerations which have merged in the discussion of taxation, both for justice and expediency.

V. The Discussion To-day.

Scientific economic inquiry into the subject of inheritance from the point of view of its purely economic effects has thus been very scanty amongst the classical economists. It is referred to, in passing, as a powerful factor in producing an uneven distribution of wealth, but its influence upon the direction of wealth production, or the actual aggregate

[2] *Principles*, B. II., Ch. II., §4.

mass of such production, has, so far as I am aware, not been really analysed. The economic aspect of the subject suffers from the fact that it has nearly always been developed in an environment of political thought rather than scientific analysis—of a programme of social change to be formulated or supported. As a consequence, therefore, assumptions have been made and adopted, without critical examination, as the basis of the case which the economist ought to admit only as the conclusion of abstract argument or definite research. However much a politician may desire to 'get on' with the argument and develop his theme, and therefore treat as axiomatic a common belief, the economist who treats his science seriously is hardly justified in imitating him.

The normal approach to this subject is by way of innate or instinctive ideas as to social justice, based upon a study of distribution of product. It is pointed out that large individual fortunes exist side by side with extremes of poverty, or that a large proportion of the national income is enjoyed by a relatively small fraction of the people. It is suggested that the inequality arises from inheritance as an exercising cause, which therefore serves no socially useful purpose, or even a socially harmful purpose. It is stated to be an offence against the general sense of the fitness of things. The tendency by way of reaction is to assume that if the right of inheritance did not exist the economic condition of affairs would not be similar, and that current economic problems would tend to be simpler and on their way to solution. This may indeed be the case, but it is not demonstrated. It may be one of those lucky instincts for political truth which the popular mind sometimes possesses. On the other hand, having regard to the unlucky instinct for error which popular economic ideas have been shown by experience to entertain, it is rather much to expect that in this particular matter instinctive judgment can be wholly trusted to dispense with analysis, reasoning, or research. To put the matter quite bluntly, any assumption that an apparent social injustice is also an economic ill is a *non sequitur*. I am using the word 'economic' in a strict sense, viz. in relation to the aggregate production of goods and satisfactions which are exchangeable, and which are produced in response to human demand and for human satisfaction, together with their distribution to individuals. I use it in no ethical sense, and am not concerned with whether the things produced in response to demand, or first produced and then provoking demand, are the things most worthy of human effort, or most likely to lead to the highest types of life, or even in the long run to give the highest forms of happiness. To bring in these conceptions would be to overweight the argument and analysis and make it intractable. It is quite sufficient to deal with those aspects which are uppermost in the ordinary mind, that is, purely material welfare, the greatest quantity of objects of desire produced for the least human effort, the question of worthy use and aim being entirely begged until the economic conclusion is introduced into a set of considerations for 'the whole duty of man.'

Dr. Dalton, in his valuable work on 'Some Aspects of the Inequality of Incomes in Modern Communities,' summarises much previous observation on the subject of the effect of inheritance on the *proportions* of distribution. The different national practices in regard to inheritance may also be conveniently studied in his book, from which will be realised

that the right of inheritance is not an absolute right of property, but has varied much in different places and at different times even in this country. (I have written a short note upon it myself in the introduction to the English edition of Rignano's 'Social Significance of the Death Duties.') Dr. Dalton concludes that the effect of inheritance upon distribution of wealth has been almost ignored by economists.[3] He takes the view that inequality of incomes is due not merely to the direct influence of bequest, but also indirectly because inheritance enables some to have higher earning power than others. But he does not specifically deal with the subject of the aggregate wealth to be divided.

Prof. Hobhouse in his book on Liberalism says, 'Inherited wealth is the main determining factor in the social and economic order of our time,' with particular reference to the existing distribution of the common product. But there is no examination of its actual economic tendency in the sense in which alone an economic answer is complete. Prof. Henry Clay, in his contribution to the Liberal Summer Schools, gives us the best approach to economic analysis of recent times, but even he does not come to grips with the central problem. He takes as his starting-point the inequality in distribution of property, as deduced statistically from the Estate Duty returns, and says: 'This inequality enhances and, in part, accounts for the inequality of incomes which is the chief cause of social unrest and the chief cause of waste in the modern economic system.' But again he recognises that inequality of property is, in part, merely a reflection of inequality of incomes. People with large incomes can save and so accumulate property. It is the diffusion of wealth that to him is the central problem, and, although the allied problems are there in his mind, he too takes much as axiomatic that I think ought to be examined. Mr. E. D. Simon, in a recent address to the Liberal Summer School, avows his object to be to point out 'how *dangerous* is the social effect of the excessive inequality of wealth that exists among us to-day.' He says 'there is a strong and growing feeling among the workers that the existing social and industrial order, with its excessive inequalities of wealth, is fundamentally unjust.' And he gets the whole 'jump off' in his argument by a graphic and moving contrast between the low wages and poverty of the jute industry and the great stone mansions of the jute lords, 'set in spacious, well-tended gardens.' The recent debate in the House of Commons on this subject, when reduced to its simplest elements, consisted of the following *non sequiturs*:

There are gross inequalities in wealth, which are socially unjust. Inheritance laws bring these about, and if they were abolished wealth would be better distributed. If wealth were better distributed the average man would be economically better off. To be better off economically is to be aware of the fact and to be more contented. A sense of social justice and actual economic betterment are identical. People would then have a 'fair start in life.'

The economic question-begging, or confusions of thought on the other side, bluntly summarised, were: 'Capital is an essential of life, and the worker would be badly off if it were not accumulated. Incentive is required for this. Right of bequest is an incentive to accumulation;

[3] P. 283.

inheritance and bequest are correlatives. Therefore, if rights of inheritance were altered, capital would dry up, and workers would suffer. The worker has no real *right* to be annoyed or sulky at a system which really benefits him, and in which the appearance of social injustice is an illusion ; therefore we can ignore the fact that he actually is annoyed and sulky. Great businesses give the worker something he would not otherwise have—they depend on the right of accumulation, and therefore inheritance laws are sacrosanct.'

Now I would say that since what people think, however unjustifiably or erroneously, affects their conduct and motives, and has, therefore, economic significance, these ideas are, as existing features of conduct, economic *facts* or ingredients. But to say they represent actual economic truths, or logical economic analysis, would be very inexact.

VI. The Problem To-day.

Before we can approach to any conclusions upon inheritance laws as an economic factor, we need research and analysis to give answers to a number of specific questions, some of them quite central and critical in making an economic contribution to the subject, and others less important, but helpful.

First, we have those which depend upon an inductive study of periods and places, and which can at best be only broadly indicative of the predisposing causes :

1. Has distribution tended to become more unequal under freedom of inheritance or bequest as time has gone on ?

2. Is it most unequal where freedom is greatest ?

3. Is there any evidence that the actual standard of life and opportunity of a person of given powers has failed to improve under such a system, or has improved at a less rate than it would have done under another system ?

4. Is there any evidence that the actual modal standard is highest wherever and whenever inequalities, however caused, are least ?

5. Ignoring the *proportions* in which aggregate wealth or income is distributed, and focussing upon the increase in the aggregate wealth or income of separate communities, is there any evidence that the rate of increase is greater or less in communities with most liberal rights of bequest ? (This is similar to 3 stated in another way, and disregards the effect upon average wealth which an increase or decrease of population, stimulated by increasing prosperity, may have.)

Second, there is the group of questions bearing on the importance of inheritance amongst all the factors which promote inequality.

6. What other factors besides inheritance are held to promote or maintain inequality, and what is their relative importance in such causation ?

7. What proportion of the number of recipients of the larger incomes draw such incomes wholly from invested sources ? What proportion of the total *amount* of income drawn by the recipients of the larger incomes comes from sources unconnected with their personal toil or enterprise ? (This is essential to help us find the relative importance of inheritance under question 6.)

8. If cessation of inheritance could in itself bring about even distribution, what would be the maximum effect on the average worker?

Third. Next we have to consider, *a priori*, whether the even distribution test is the economic *summum bonum.* This involves psychological factors, and whether anything is economically good in itself if thinking does not make it so.

9. Is absolutely even distribution an economic, as distinct from a social, ideal? *i.e.* will wealth production be at its maximum in quantity and quality?

10. If not, at what point is 'gross' inequality reached? By what standards, absolute or comparative, does one conclude that a given range of inequality is 'gross,' 'indefensible,' and, above all, economically disadvantageous?

11. Is a 'fair wage' a relative or an absolute idea? *i.e.* in view of differences between different epochs and countries, is there any evidence that men's ideas are sufficiently stable for a 'fair wage' finally to be reached? How far is it the product of difference of station?

Fourth. Then we have to ask, what motives, with any economic effect, are set up in the human mind or will, by a system of free bequest?

12. Is the right of bequest an overmastering factor in capital accumulation? What proportion of capital accumulation would go on without it?

13. Is the sense of social injustice arising from it of economic significance in aggregate production?

Fifth. There may be directional, or partial, as distinct from aggregate, advantages in a system, which are a useful ingredient in social and economic betterment, *i.e.* variety and stability as against mere quantitative tests.

14. Does the right of bequest best preserve economic values which are of importance in particular directions, *i.e.* consolidation of estates, hindrance to natural development, the conservation of amenities as against utilities, continuity of policy, &c.?

Sixth. In the last group we have a series of inquiries which approach the problem from the reverse direction, and also have a highly practical bearing.

15. What are the economic consequences of discouraging or nullifying bequest and inheritance by heavy taxation? Is there any evidence to show that its distribution is made more even in this way, *ex post facto*, or that aggregate wealth-making is discouraged or wealth-making capacity is reduced?

16. As regards the many who benefit, what is the effect upon motives towards production and towards psychological contentment?

17. As regards the few who suffer, what is the effect upon motive to work and to save? Must a given amount of taxation laid upon a given amount of capital wealth left at death have the same total effect, however it is imposed? Is it possible to arrange the imposition on any principle which will depress wealth-making motives to a minimum degree and fall more heavily at points where the harmful economic reactions are least?

There is a seventh group of questions which deal with the broader aspects of inheritance.

18. As other things besides objective wealth are inherited, can wealth be really or effectively dissociated from them?

VII. Comparative Inequality of Distribution.

I regard the foregoing imposing schedule of questions as all pertinent to the economic inquiry. To some of them we have at present no answer at all; to others we have a partial answer or general indication; to others, again, a little reasoned analysis will afford us a high degree of probability. Within the scope of this paper I cannot do justice to all these questions or explore them all. I may perhaps summarise what we know in regard to some of them and give provisional answers to a few and suggest my views on others.

I. I have been able to find no positive evidence that the slope of distribution has materially changed in the past hundred years.[4] The scale of wealth is different and the whole population is strung out on the line further up. There are probably at the very top much richer men, and wealth on a scale unknown in former times. In this way I think that a given minute fraction of the people holds to-day a slightly larger fraction of the total income. So much of this has arisen, in the cases of great wealth, from activity during the income-receiver's life that it is not so much a part of the problem of inheritance as of distribution of the product of industry, the potentiality of the industrial system and accumulation of savings during life. This broader aspect of distribution is not the subject of our discussion. Some forces tend in an opposite direction, *i.e.* to lessen the centralising force of bequest: Heavy Death Duty taxation on these large aggregations, and the lessening importance of land in total wealth, and the weakening influence of primogeniture, which makes for family diffusion rather than concentration. Even if the distribution slope has not greatly changed, probably the inheritance system affects the angle of the existing slope. Prof. Pigou remarks, in regard to the alleged immutability of the Pareto law, that income depends not on capacity alone, but on a combination of capacity and inherited property, and the latter is not distributed in proportion to capacity but is concentrated upon a small number of persons. This must deflect the curve from its normal form. The actual form cannot, therefore, be 'necessary' unless the broad scheme of inheritance now in vogue is also necessary. But a very large change in the existing laws is not essential to bring about a great difference in the income curve, since property is more unevenly distributed. Thus $76\frac{2}{3}$ per cent. of the population owned only 7 per cent. of the property, but 73 per cent. owned $35\frac{1}{2}$ per cent. of the income. (Clay: 'Property and Inheritance,' p. 19.) As regards the United States, Watkins ('Growth of Large Fortunes') says: 'For wages, the upper decile is less than twice the median down to 5/4ths the median. For salaries it is twice the median, and for property eight times the median.' So far as Great Britain is concerned, the statistical indications are that static redistribution to-day would not add an appreciably different *percentage* to the modal income than formerly. Statistical evidence for past years for other countries on this point is too scanty to be of any use. There are no distribution figures of any value for Germany prior to 1890, and none for France at all, while the United States figures are good, but quite recent, and no comparisons with earlier times are possible. Research

[4] *Vide* my *Wealth and Taxable Capacity*, iii.

in this field, I believe, will be barren, and in the case of the United States, owing to other powerful factors, the figures would be inconclusive.

2. Distribution seems to me to be probably less unequal where bequest is trammelled, *i.e.* the 'légitime' in Continental countries makes for family diffusion and equality, as in France and Germany. But, for what it is worth, we must observe that the two richest countries have freedom, and the next two in order of wealth have conditional bequest. The only considerable one (Russia) with no rights of inheritance is now sinking into poverty, but this tendency, of course, cannot be assigned merely to inheritance custom. In any case, owing to the effects of the war, the comparison must be confined to pre-war years, and the evidence will be found in the tables in my 'Wealth and Income of the Chief Powers.' There is room for research and some comparative study of the diffusive effect of the 'legitime' as compared with our own system. It must be remembered that, so far as all past wealth is concerned, without accumulation and concentrative power for new wealth being fully maintained, there must be an increase in equality, even if wealth is left to *all* the children, where the effective birth-rate for the wealthy is not maintained near the national average. If 5 per cent. of the adult population own half the property, then in the two generations (assuming a similar birth-rate to the general), without any new accumulation, and, say, three times the total population, this 5 per cent. would still own one-half, but they would be three times as numerous and their individual shares only one-third the size. Now *new* accumulation must be relatively of great importance if the individual fortunes of the richest people are to be on the old scale of magnitude. It follows, therefore, that in the economics of the *very* rich, current or immediate right of accumulation tends to be much more important than inheritance at the second and later stages. Taxation and family diffusion tend to reduce the long-range inheritance effect on the size of individual fortunes in such a way that, even if inheritance ceased altogether, the existence of the very large fortune would be very marked under the influence of other economic factors.

3. My conclusions as to the average position or actual standard of life have already been given elsewhere.[5] During the 120 years prior to the war I concluded that the real position of a typical or standard person in this country—*e.g.* at the lower decile—had improved four times. During this period the inheritance system has been fully in force. There is nothing to *prove* that the rate of increase would have been more if it had not been in force. Education and improved health have doubtless done a great deal in this advance, but probably the quota of accompanying fixed and circulating capital per head in improved machinery and transport has been the most effective feature. The question is, therefore, thrown back on to the inquiry, which hardly admits of statistical research, whether the accumulation of capital (regardless of ownership) could be as great under another system. There are four rival systems on which we may depend for the aggregate saving: (1) dependence on the better-off; (2) equalising individual resources and then expecting each individual small-income receiver to save; (3) saving through taxation; (4) collective saving (*e.g.* company reserves). In my view the third is the least

[5] *Wealth and Taxable Capacity.*

satisfactory ; the second ought to be the best, but, in fact, is not. The call of spending on a small income is great, and it is difficult to save permanently for fixed capital assets. One man with £10,000 and 500 with £100 per annum may save £8,000 with its improvement in the future incomes of the 500, but on even distribution 501 people will each have £119, and they are not likely to save £16 each and spend only £103. This is where the redistribution due to heavy taxation is affecting our present aggregate savings to-day. Although the workers are saving more, they are not making up the gap so caused. The real rival to nineteenth-century saving is the saving that goes on silently through company reserves, &c., and that never actually becomes anyone's spendable resources at all.

4. Inequalities of wealth appear to be statistically less in France and probably in Germany, and certainly in Italy. In all these the average standard of life is lower than in the countries where inequality is greatest. There is, therefore, no statistical correlation between extremes of inequality and poverty of standard. The association is probably in the opposite direction, but this is, of course, no proof of actual or causal connection.

5. The comparative rapidity of increase in total national wealth can be tested by statistics to only a limited extent (*vide* 'Wealth and Taxable Capacity'). We can enquire back to 1850 with the United States, whether other factors than inheritance are so powerful, but some research would be needed to give good comparisons for the countries with limited rights of bequest, France, Germany, &c.

6. Coming now to the second group of questions, No. 6, Dr. Dalton has analysed some of the causes of inequality besides inheritance in the work referred to. But quantitatively we know little of their relation. Probably 110 years ago, when the income from property was to the income from business as 100 to 60, instead of 100 to 400 as it is to-day,[6] the effect of inheritance and accumulation on distribution was far greater than to-day, when many of the highest fortunes have generally been made within the lifetime of the holder, without significant initial resources. I think there is considerable room for statistical research upon this matter in different countries.

7. The proportion of people in the higher ranks of income who have income from occupations or businesses in which they are actively engaged, and also the amount of the income so earned in relation to the total income in each class, is, I believe, as follows : Speaking generally for the total incomes of those with from £10,000 to £100,000, there has been a tendency for the proportion of income coming from earned sources to increase, and it would now be about 30 per cent. The proportion of the incomes over £100,000, of course, is rather lower. I have no means of knowing how much of this 70 per cent. comes from savings accumulated within the lifetime of the possessor, and how much from inherited wealth ; but having regard to the rate of increase of the national wealth in the past fifty years, and the rate of increase of the inheriting population, it is probably a much smaller proportion from inheritance than is popularly supposed.

But when we come to consider how many of the rich people have an occupation earning income, there are over 70 per cent. earning and under

[6] Vide *British Incomes and Property.*

30 per cent. who have investment income only. (In the highest incomes the percentage of incomes from investment only is much smaller.) Out of this 30 per cent. a good proportion are of course doing voluntary unpaid work as magistrates or in other public positions; another section comprises women who have no opportunities; while another section would be men too aged to work. As you know, the larger investment fortunes tend to be concentrated on the higher ages. On the whole, I should doubt whether the percentage of able but *unoccupied* men living entirely on investment income in these classes exceeds 10, and it may be as low as 5 per cent., or, say, under 1,000 people.[7] The actual *numbers* of the 'idle' in the classes from £1,000 to £10,000 would exceed this by far, but I have no means of knowing whether the percentage is greater. Moreover, of those gainfully employed, only a minority are drawing their earned incomes solely from directors' fees, and the majority have industrial or financial activities in which they take a personal part.

8. I think the only test of the effect of equal distribution of wealth upon the average worker would be by distribution of the income. I have already published my statistical conclusion that if all the incomes in excess of £250 were pooled, then, after deducting the present taxation and a fund of new savings equivalent to the pre-war real savings, it would not give each family more than 5*s*. per week.[8] But much of this redistributed income is earned income, and therefore the redistribution of property income would give spendable income falling below this figure. There is room for research on this question for the United States, France, and Germany.

VIII. The Standard of Life and Psychology.

The third group of questions deals with the psychology of the standard of life and of equality of distribution.

9 and 10. There is as yet no economic evidence that equality of individual income, whether derived from earnings or from property, would give the maximum economic advantage. Nor is there evidence that equality of investment income added to unequal earned incomes would give an optimum point for national production. There are three possible assumptions:—

(*a*) That the community should take over all accumulated savings at death and hold them for common enjoyment in new social services in common forms, and in payment for all public services; (*b*) that the population should receive the income and dividends by equal sharing; and

[7] Since 16 per cent. of the large estates corresponding to these supertax incomes are left by women, we may deduct 5 out of this 30 per cent., leaving 25 per cent. for men. But since out of all estates of the magnitude left by men, 76 per cent. are left by men of over sixty-four, this leaves only 6 per cent. out of the 30 per cent. for younger men. Making due allowance for mortality rates in the estate distribution tables, the estimate in the text is reasonable.

[8] Vide *Wealth and Taxable Capacity*, iii., and *The Christian Ethic as an Economic Factor*, Appendix III. Also Bowley: *Distribution of the Product of Industry*; and Chiozza Money: *The National Wealth.*

(*c*) that compulsory family diffusion would do something to mitigate concentration in Britain and the United States.

I have referred above to effects upon accumulation of savings which I regard as of enormous importance in economic advance.

One may learn something from the proved effects of remission of taxation and social expenditure, that direct additions to individual resources soon exhaust their effects as direct additions to that kind of contentment which makes for incentive to greater or better output. The addition becomes the expected and the normal, and there is no evidence that an improved standard of life in fifty years has made, through *incentive* alone, for harder work. It has made a physically better worker, and improved output has proceeded from this cause. In fact, even short-period effects are often disappointing, and a betterment of conditions through improved rate of wage has been partially offset by claims to shorter hours by regulation or absenteeism. Here psychological effects are not identical in different countries, and by no means all the workers aim at working long enough or short enough, as the case may be, to bring in a normal wage. If this is the case for additional direct rewards, it is pretty clear that indirect additions to income through parks, libraries, roads, &c., are much more removed as a direct stimulus to increased economic effort. A small minority of workers will respond to the social idea in which their additional effort will not enrich the few and carry down the unearned property of those few to the select heirs. As regards those whose incentive is being considered from the point of view of deprivation of the privilege of bequest, we may study these later. A more even family diffusion presents a difficult problem, which the example of France does little to elucidate. Those who base their views as to the effects of inheritance not so much upon the facts of inequality as of its extent, its 'grossness,' do not indicate at what point inequality ceases to be defensible and becomes mischievous. We are entirely without guidance upon this subject, nor does it appear that there will be a consensus of view upon it sufficiently stable for common action. One cannot be dogmatic upon this, because a similar lack of standard exists for fixing proper rates of progression in taxation; but the problem is roughly, though only temporarily, solved in practice, and progressions tend to increase in steepness, the instances to the contrary being very few. Just as ideas about a fair standard of life are relative, so ideas about the weight of taxation are relative too. If anyone doubts this, let him read the Parliamentary Debates on the subject of the income-tax at 1*s*. 3*d*. in the £, which was 'gross' and 'indefensible' and 'disastrous.' I think, therefore, that it would be exceedingly hard to say at what precise point between 1·3 and 1·8 in the $\propto$ slope of the Pareto line the line becomes either economically indefensible or an offence against social justice. I am impressed with the importance of a general popular sense of social injustice as a basis for political ideas, in the absence of exact standards, but I distrust its finality as an economic conception.

At the same time, men are moved in economic action by motive, and the motive is no less potent because it is incorrectly or inadequately informed.

It is my conclusion, after much study of men's attitudes, that they are

much more affected by comparisons than by absolute facts.[9] Under a state of affairs in which accumulation, inheritance, and bequest have been the rule, A finds himself in possession of 10 units out of a total of 10,000, and he sees B enjoying 1,000 out of that total. His assumption may be that if the present practice of inheritance did not exist, but some other practice obtained in its place, he would enjoy some different number, a number, in his judgment, much more than 10—say 20—and B would have less, say 500. Or perhaps he assumes that equality would reign, and that with 500 inhabitants each would enjoy 20. This, so far, is only an argument *post hoc ergo propter hoc*, for, failing demonstration, some other reason may exist for the difference. But it is almost invariably assumed in this, as in other discussions of distribution of wealth, that under a system in which inheritance was not the rule, the aggregate production to be divided would be at least the same—viz. 10,000 units—whereas of course it remains a probability that it would be either less or more, and an improbability that it would be identical, for the inheritance system must have *some* appreciable economic effect on accumulation and production. Suppose, for example, that inheritance, whatever its effects on distribution, has a net beneficial effect on aggregate production; then it might well be that, instead of 10,000 units, there would in its absence be only 8,000, of which A would have 18 and B 500—that is, the distribution is not so extreme, though, measured absolutely, all are worse off. Now men are not given to the comparison of absolute changes, mainly because they are not available at any moment of time, and are at best historical. They do not compare their own absolute position at one moment in their actual condition with what it would be in hypothetical conditions. Neither does it impress them very much if it is proved to them that under the existing scheme of society they are four or five times as well off absolutely in goods and services as their forefathers in similar circumstances a hundred years ago. They compare themselves with their fellows at the same moment of time. So a man may be even worse off absolutely, but his sense of social justice will be less offended if the difference between himself and B is less marked than it was. He would rather have 10 per cent. of a moderate cake than 8 per cent. of a larger one, because he is always comparing his angle of the sector with another man's angle or the length of the arc, but never thinks of the cubic content. As a matter of fact, any sense of injustice in distribution based upon this attitude of mind is a very poor measure of actual economic welfare.

We can thus postulate three possible positions of the economic aggregate for a community which results when a system of unlimited inheritance is banned as compared with a system where inheritance is in force. The first is that it would be lower, the second that it would be the same, and the third that it would be greater. But this tells us little about the

[9] Dr. Dalton, in touching upon ambiguities and confusions between absolute and relative shares, dismisses this aspect by accepting it. 'Though absolute shares are the chief determinant of actual economic welfare, relative shares are one of the determinants of the potential economic welfare, which might be realised under a different scheme of distribution. Human psychology is such that the satisfaction, and hence the economic welfare derived from an income, depends not only on the absolute size of this income, but also on its relative size as compared with other incomes.' *Op. cit.*, p. 161.

fortunes of a particular person A of given ability and energy in that community. These three cases may be subdivided to give twelve conceivable positions.

1. *Where the aggregate is lower than* 10,000, *say* 8,000 *units.*

	A's actual position.	Wealth distribution and A's sense of justice.
(*a*) A's fraction higher than 1/500th and actual sum greater than 20—say 25 or 1/320th . . .	better	better
(*b*) A's fraction higher than 1/500th, but actual sum the same—say 20 or 1/400th	same	somewhat better
(*c*) A's fraction the same, but actual sum lower—say 16 or 1/500th	worse	same
(*d*) A's fraction and actual sum both lower—say 15 or 1/600th	worse	worse

2. *Where the aggregate is the same*—10,000 *units.*

	A's actual position.	Wealth distribution and A's sense of justice.
(*a*) A's fraction higher than 1/500th and actual sum greater than 20—say 25 or 1/400th . . .	better	better
(*b*) A's fraction and sum the same—20 and 1/500th .	same	same
(*c*) A's fraction worse and actual sum lower—say 16 or 1/625th	worse	worse

3. *Where the aggregate is higher, say* 12,000 *units.*

	A's actual position.	Wealth distribution and A's sense of justice.
(*a*) A's fraction higher and actual sum higher—say 1/400th or 30 units	better	better
(*b*) A's fraction the same and actual sum higher—1/500th or 24	better	same
(*c*) A's fraction lower, but actual sum higher—1/545th or 22	better	worse
(*d*) A's fraction lower, but actual sum the same—1/600th or 20	same	worse
(*e*) A's fraction lower and actual sum lower—1/800th or 15	worse	worse

On the assumption that it is a definitely higher *fraction* of the total, as distinct from a definitely better absolute amount, which will give rise to a feeling of greater contentment or a less sense of social injustice, it is

clear that there are only three out of twelve possible alternatives which can yield the required result, although there are five possible cases in which A may be actually no worse off and five in which he may *feel* worse off.

Here I may pass to question 13.

To what extent does a *feeling* of social injustice operate to affect a man's motives to make him work harder, or less hard, or work less regularly, and thus in itself become, psychologically, an economic factor affecting the aggregate production? It is only in certain special circumstances that the feeling will lead to harder work. It would do so where an effort to escape the inferior position is great, but this is hardly distinguishable from the incentive which is afforded by the prospect of wealth, and of distinction itself, which must be examined later. It is probable that with many temperaments the feeling operates to exasperate, not, indeed, all the time, but at occasional periods when the difference is brought home by some marked external incident. It is probable, therefore, that it contributes to an underlying feeling of unrest, and a complete unwillingness to do more for the wages obtained than the minimum that will pass muster. There must be many thousands, even millions, who continue to accept inequality, not so much of wealth, as of wealth due to *inheritance,* as part of the scheme of things against which they have little grievance. They are believers in 'luck,' and coming into wealth from a forgotten uncle in Australia may move to envy, but it does not lead into malice or resentment. These vast numbers are sufficiently untouched in their economic activity by a sense of social injustice in everyday life not to work less faithfully or less hard. There are, however, numbers who, in times of distress and unemployment or labour trouble, can be brought to considerable moral reaction against any display of luxury on the part of the 'classes' who do not work for a living. We have heard of the resentment against mining royalties, which as a peculiarly provocative form of inherited wealth are contributory in a marked degree to that lack of good feeling in the mining industry which has a marked economic significance in output. In my judgment the feeling of resentment against wide differences of fortune due to inherited wealth is seldom distinguished in popular feeling from differences due to the right of accumulation as distinct from inheritance. It is the inequality of reward and the multiplying power of accumulated wealth which excites animosity, not so much that particular part of it which may be due to the inheritance system. I find it difficult to believe that a sense of social injustice *addressed simply to the existence of a system of inheritance* is, in itself, an important economic factor. The average man is unaware that inheritance is not a 'natural right' existent at all times and in all places. If he has any sense of injustice it is against inequality in general, and not to inequality as brought about by this system.

I have made many inquiries in America of workmen and of those who are in touch with them and know their psychology, and I am assured that grievances about inheritance as such have no adverse effect whatever on production. Indeed, I was assured that inequality of wealth, to which this is contributory, stirs men to effort, to emulation, to ambition, and

gives a dream and a goal. In this sense the inequality serves to urge many to greater efforts than would otherwise be made if all were on a dead level of attainment and power.

At the same time, so far as this country is concerned, if there were no inherited wealth at all, it might be easier for the average mind to accept as inevitably associated with difference in human capacity, and even with the luck of the game, inequalities of fortune arising entirely in their own lifetime. But the rooted practice of the 'légitime' in France gives an entirely different outlook upon the abolition of inheritance altogether in its psychological influence.

I can give the answer to question 11 only generally, viz. that ideas concerning the standard of life and fair wages are relative and not absolute. As arrived at subjectively, they are of little use as an indication of economic actualities or possibilities. I have dealt with this elsewhere.[10]

The right of bequest and the right of inheritance respectively may differ as incentives. When we come to consider the effect of an inheritance system, we have four sections to study. We divide, first, on a time basis, into those living at the time wealth is accumulated in response to the stimulus of the system, and those living at later times when the wealth accumulated has been inherited, and when the system has the effect of 'dictating' the distribution of currently produced wealth. Again, we divide the people in each period into two functional sections, those who do the accumulating and those who watch others do it.

Here we are in the field of personal views about human psychology in the mass, although the statistics of the growth of life insurance, and the proportion of wealth left out of the direct family line, are valuable. There is room for research into systematic life-insurance statistics, but the indications are clear that the family-provision incentive (including a buttress against death duties) is more powerful even than formerly. There is fair statistical evidence that the proportion of amounts bequeathed to distant relatives and 'strangers' to those bequeathed to close relatives was relatively stationary in the depressed eighties, and, with the rising tide of prosperity in the twenty years before the war, slowly rose and has since fallen. Two kinds of incentive must be distinguished—the first is to save more out of a definite income or work, and the second is to produce more in order that still more may be saved. Two kinds of objectives must be distinguished: first, provision for old age merging into provision for a surviving widow, but irrespective of children's welfare; and, second, provision definitely for children or others. A positive and a negative side must be distinguished: first, the positive right to bequeath may have less importance in creating savings that would otherwise not exist, than the knowledge that all savings would be annihilated would have in stopping savings coming into existence at all. If there were no power to bequeath by *inter vivos* giving, there would be a great tendency to individual *de*cumulation.

My own view, after long consideration of the available data, is that the power to bequeath savings that will remain intact is a most important factor in wealth accumulation and saving, and the desire to leave these savings for the direct line, children and grandchildren, is an important

[10] *Wealth and Taxable Capacity*, iii. Also *Christian Ethic as an Economic Factor.*

special case of that incentive.[11] But I am equally convinced that the mental horizon, which is so powerful an agent in business calculations during life, which reduces the present value of a reversion over fifty years hence to a negligible figure, is even more restricted for events after death. The fate of one's savings, with the special case of landed estates ruled out, after, say, thirty or forty years, has but a negligible influence on present effort or production. I therefore accept the popular estimate of this incentive, but I emphasise it much more in its immediate effects and belittle it much more in its final effects. This distinction is of great importance in the theory of taxation.

As regards incentive to the recipients, it is possible to exaggerate its influence in making idle men, who would otherwise add more to the mass of production. This effect really exists, but it is a very slight percentage of potential production, however glaring individual cases may be. A man who has great capacity to add to production and raise the general standard, has enough character not to be idle and unproductive simply because he has other means; indeed, he may play less for safety and be a risk-taker and pioneer, and so add to economic welfare. The gilded idlers would not, in any case, have made much greater economic additions than their own subsistence. I am not referring to moral or ethical aspects, of course.

But the effect upon subsequent saving and accumulation is most important. A man with an inherited fortune of £20,000 who works hard and makes, say, £1,500 a year, has no strong incentive to do any more saving out of his combined income of £2,500, and may be content to pass on the £20,000 intact. But for this fortune he might have been a *new* saver. I think there is singularly little statistical evidence of *accumulative* saving, and while inheritance sustains inequality, it does not greatly increase it; the old inequalities of fortune are fed from new inequalities in earning and the immediate bequests made from that source. I doubt, therefore, if the deterrents to saving which high death duties create are so important in their final effects when one considers the increased incentive to new saving (and perhaps effort) which the lesser fortune to the recipient brings about.

IX. Special Cases of Inheritance.

(*a*) Land.—One of the most obvious ways in which the laws or practice of inheritance move to a direct economic result is in the sphere of land tenure. Clearly, there will be a *prima facie* difference between the agricultural conditions that would exist after a long period of compulsory division of property on Continental lines as compared with centuries of primogeniture and the desire to maintain large land-units intact. There have been certain important changes lately in the law of property which

[11] For estates over £1,000, 80 per cent. of the married men and 90 per cent. of widowers have children living at the time of their death, while married women and widows have children in 68 to 70 per cent. of the cases. There is no weakening of these figures—if anything, the reverse—in the higher sections. In 10 per cent. of the cases of single men there are parents living at the time of death. Intestacy, of course, decreases with the size of the estate, and in the case of single men, for estates exceeding £1,000, over 21 per cent. die intestate; but in the case of married men it is under 10 per cent., and even less for widowers.

may have economic reactions, but I am leaving the whole of this field to the succeeding paper by Sir Henry Rew on the effect of land-tenure systems on production.

In stressing the importance of the right of bequest without diffusion, reference is frequently made to the continuity of management and interest in large businesses. A man of energy and resource builds up a great business, and one of his incentives is the knowledge that he is training his son to follow him and make it greater and better. The old instinct which vented itself in landed estates passes to commerce. It is urged that the right to bequeath and the power to keep the control in the family has been an actual feature in economic development, in this country at any rate, and a study of the history of typical firms, especially in the North of England, during the first three-quarters of the nineteenth century, does much to confirm it. But it is doubtful whether such a practice occupies a sufficiently important place to-day to deserve a front place in the general argument. Two modern features have seriously influenced it. The first is the growth of an independent managerial class as a profession who can, for a salary, pass from business to business and lead its administration. The second is the facility with which private businesses at the height of success pass into the joint-stock form, often with a public issue of preference shares, and the family taking the cash and retaining the equity.[12] The percentage of profit made by private businesses out of the total changed from 70 to a little over 30 in a period of forty years. It would be a bold thing to say that a big business depended to any serious extent upon continuation of direct family control or interest for a number of generations. On the contrary, the infusion of new blood and outside interest has rejuvenated many a business that has been living on its traditions. The death of a rich part-owner rarely affects modern business. The proportion of wealth, excluding War Loan, passing in the form of shares at death, has increased from 32 to 48 per cent. of the whole in ten years. However important this element of inheritance may have been in the past, it is now relatively insignificant in dealing with the whole mass of accumulated saving.

A correspondent who raises no claim to be an economist sends me a thoughtful letter in which he says :—

'I live in the country and have some opportunities of observing and reflecting upon the *more primitive social and economic order* of the countryside, centuries behind the specialised professional labour of the city only a dozen miles away. As long as sons generally followed their father's trade—as I suppose they mostly did in England until a century ago—it seemed reasonable that *a son should inherit his father's tools*, and this not so much because he is a son as *because he is a junior partner in business.* For any outside body, parish, county, or state to step in with an extraneous claim to these tools or to some of them is simply to shatter the economic order and the chance of maintaining production just when the business

[12] *Vide* Chapman and Ashton on 'Sizes of Businesses' (*Statistical Journal*, 1914) and 'Growth of Textile Businesses' (*S.J.*, 1926). Out of 221 concerns in 1884, 127 were private firms with a modal size of 20,000 spindles, the mode for companies being about 80,000. In 1924, out of 203, only 5 were private, with 20,000 spindles as a maximum. The mode of the companies was about 110,000 spindles.

is hard hit by the loss of its senior partner. To-day "tools" might be interpreted in the city to include a factory and all its machinery; in the country 1,000 acres of woodland is a means of production using the sun's radiant energy instead of coal. The limited liability company is a shock-absorbing system in the economic order of the city, and factory work goes on in spite of the funeral of a director. In the more primitive order of the country the death of the landlord may paralyse his estate. Even if one were to accept the argument that big estates ought to be broken up into small estates (no matter whether these would be more or less remunerative per acre), one effect of heavy death duties levied on rural estate is to withdraw capital from agriculture at a most inconvenient moment. Death duties on a landlord's personal effects—pictures, furniture, &c.—might have one sort of justification—the distribution of luxuries. Death duties (in excess of one year's rent on land) may mean the paralysis of repairs, fencing, draining, planting, &c., for years, and inhibition of capital development for decades. It might be more defensible if death duties on land all went to the Board of Agriculture, to be redistributed to the same industry in the form of agricultural education, expert advice, new breeding stock, &c. But the drain on the *capital sources of the industry* (to be distinguished from the drain on individuals) has widespread effects which need not be confused with the whinings of discomforted individuals. The old order accepted disposition by will to the family; it was justified as long as the family continued the business. If the families do not continue the business, would it be wise to initiate a new order in which *inheritance should go by occupation*, so that if a manufacturer died intestate his employees would succeed to his factory, so that legacy duties should differentiate not in favour of near relatives, but in favour of those in the same business, so that if there were any death duties these should go not to the State but to the trades union, or in bonus shares to the employees?'

Businesses both of landowning and of commerce have become so impersonalised that no great case for unlimited powers of bequest for economic reasons can be based on the objective personal link. We are thrown back on the subjective factors.

X.

In the sixth group, with questions 15 to 17, we touch upon the large question of the influence of taxation, and it would take me too far afield to deal with them at all adequately, because they involve comparisons with the effect of alternative methods of raising revenue. But the Report of the Colwyn Committee on Taxation and the National Debt, with which I am concerned, will, when issued, probably deal with many features germane to this address. I will content myself with saying that if practical considerations are ignored, to raise a given revenue with some reference to graduation by order of succession and time on the Rignano principle, and to extend the graduation of taxation of bequests outwards by relationship, would, in my judgment, offer some important economic advantages over the present methods of raising the revenue.

XI. Inheritance of Ability.

The principle of the inheritance of wealth is complicated by its biological affiliations. A man has certain qualities which make for distinction and success in himself and for unusual service at the same time to the community. His son may inherit a full or partial measure, and this inheritance is a factor of economic importance, making both for an uneven distribution of the aggregate of wealth, which is obvious, and also, what is less obvious, for a greater economic aggregate for all to share. Now such inherited powers, so far as they exist, are a part of nature, and cannot be gainsaid, nor abrogated nor repealed. But in a developed national science of eugenics, in a socialistic community with a certain type of socialist ideal, in which equality of division of wealth (or wealth-making power) is counted as of greater importance than the greatest accretion to aggregate wealth unevenly divided (by which the individual benefit may be even greater after subtracting the rich man's portion), it would be logical to direct human mating so that inherited tendencies to superior wealth-making powers should be diffused or defeated. If it were found that the mating of types A and B would perpetuate a characteristic particularly forceful in economic affairs for the individual exercising that characteristic under the hedonic stimulus, and not exercising it under any other, but that the mating of A and C would obliterate it, then the obvious duty of those who put equality of wealth as paramount would be to promote eugenic laws that discouraged A and B and encouraged A and C to matrimony. But I do not wish to pursue this type of eugenic speculation. I am dealing with the inheritance of qualities, only because of the argument that a man's accumulated wealth is an objective extension of his personality, a material result of his qualities, and that if nature passes on the effective element of his personality to his heirs this extension logically and legitimately, by social sanction, goes with them.

In my judgment, while we are apt to regard the cultivation of mental, moral, and physical qualities, and their effect upon future descendants, as biological problems, internal to the human organism, we also tend to regard those extensions of a man's personality which are reflected in his ability to acquire and accumulate belongings around him, as purely economic. No such hard-and-fast line is final. A man may enrich his life by the expenditure of a part of his income in immediate travel and widening of his powers and knowledge, or he may externalise it by the acquisition of works of art, or he may put it into the field of economics by saving that portion of his income so that it will yield him an income which will perhaps enable him to travel or to extend his personality in some way or other in years to come, after he has ceased to be an earner. Similarly in his treatment of his children. For one he may spend a large amount of money to make him a professional man, a doctor or solicitor, in which case the bequest or inheritance goes on without any obvious sign of his 'leaving' wealth. To another son he may leave an equivalent amount to be invested in a business, and if they are men of equal ability it may be assumed that the income from personal effort and invested capital will be similar in the business and in the profession. In the one case the effect of inheritance is clear; in the other it is masked. Nothing

can stop him bequeathing certain personal qualities of character and the environment of early life to his children, and they perhaps, in a less marked degree, to his grandchildren, but that extension of his personality which represents the modification of their environment by their control over saved wealth seems to be on another footing. But a man conscious that his sons were 'fitted' in the best sense, and that they ought to survive, could help their survival both by personal training and also by accumulation of wealth which he bequeaths to them, in either case representing personal self-denial, and in either case representing some quality imposed upon their human environment. Whetham, in 'The Family and the Nation,' says that unless the fittest to survive hand on their qualities to a larger number of descendants than are left by the failures, natural selection cannot act. It is of no use for an organism individually to survive unless it transmits the character which enabled it to do so to a preponderating number in succeeding generations. A struggle for life and the survival of the fittest are meaningless alone; the qualities of the fittest must survive superabundantly his own fleeting existence if the struggle and the survival are to produce any good effects on the race. The bequest of some investment income to a man undoubtedly enables that man to be freed from some of life's cares, and in that sense to devote himself more closely to his pursuits, and to make him more fitted to survive. The qualities that brought about the original accumulation have had social advantages, and the reflection of those qualities is in their tangible objective results *plus* the subjective capacity for continuation of them. Whether qualities are inherited in a great measure or a small, and whether they are important as economic factors, I am not greatly concerned, for such inheritance, so far as it is a fact, is unalterable, and I am pursuing this subject more with its bearing upon practical social action in mind. So if biological inheritance is marked and substantial, the argument for transmission of accompanying wealth may be relevant. But if biological inheritance is wayward or unimportant, the bequest argument, however closely knit to such heredity, has certainly no *greater* force. Suppose that it could be shown that only in one case in ten thousand does the distinctive personality of a parent descend to his son. Then, even if the argument that objective extensions of that personality should not be separated from it were fully valid, it could only apply to one case in ten thousand. Moreover, even if the biological descent were effective one hundred per cent., the doctrine does nothing to support freedom of bequest or primogeniture or the British ideas at all. If the argument is valid at all, since every child would share its parents' personality, every child should share the parents' wealth, and the doctrine leads towards family diffusion of fortunes on the Continental principle of 'légitime,' and would discontinue all bequest out of the direct blood descent, to collaterals, &c. Besides, even in the direct line any force the argument possesses is greatly weakened. If a man can claim on biological grounds his inheritance of ability from a great-grandparent to be a merely fractional part, qualified and diffused by his inheritance from seven other primary sources, then his right to rank his claim superior to the rest of the community for the inheritance of the whole of the wealth is equally tenuous. Nevertheless, the biological argument may have some economic 'point' so far as the

first generation is concerned, mainly when it is viewed in its eugenic setting, (1) *Heredity in genius exists to a definite extent, and this fact has economic value to the community*, since, if one dare put a qualitative aspect in quantitative terms, a community of 100 persons of n degrees of ability *plus* one with 100 n degrees, will reach higher economic levels than a community of 101 persons each with $n+1$ degrees.

The starting-point of any consideration of the inheritance of ability is Sir Francis Galton's great work on 'Hereditary Genius,' published in 1869, and recently quoted with approval by the Whethams in their book on 'The Family and the Nation,' in which the most recent eugenic and biological views confirm Galton's works. Galton found that the proportion of eminent men in the population—that is, eminent in the sense of having manifested unusual ability—was about 250 in the million, or about ·025 per cent., and it was found that the chance of the son of a man of great ability, such as a judge, himself showing great ability, was five hundred times as great as that for a man taken at random. (You must refer to these works to see the effect, upon these chances, of marriage with an able or an ordinary woman respectively.) The Whethams state as a conclusion: 'As long as ability marries ability a large proportion of able offspring is a certainty, and ability is a more valuable heirloom in a family than mere material wealth, which, moreover, will follow ability sooner or later.'

They say: 'Since the assumption of the responsibility of offspring falls on those of the younger generation whose financial position, even in the upper classes, is usually not yet secure, it should become an increasing habit for the older generation, where they have it, to distribute a substantial part of their property during their lifetime. Such a distribution should not excite the animosity of the Chancellor of the Exchequer. Security or affluence often comes too late to make easy the heavy burdens of early maturity, and when it comes provides but bitter reflection over lost opportunity. Those in the prime of life can make the best use of wealth in the service of the nation. May each generation as they grow older learn to relinquish it in time to watch their successors meet their responsibilities fully.'

Let us assume that the peak responsibility of the average married couple is reached at a period in their lives when they have not got to their highest earning power, and that they could do better for their families—educate them better, and bring them up in a superior style—if they had some assistance from outside.

There could be no better eugenic or sociological institution than a kind of moving annuity which should pass from generation to generation, not at the death of each person, but from him to his children at a point when his personal need for it has become less, and when his son's need for it has become greatest. The inheritance would not, therefore, be one passing at death, but would be one passing at middle life; it would be like a permanent endowment of the family at its most difficult periods, and there could be no more honourable object of ambition than to endow one's family and descendants in this way, because it would be of the highest eugenic value to the community. In middle life a man cannot both save for his old age and retirement and also spend the best of his

income upon his family. It is here that the inheritance from the previous generation, coming at an earlier date, would enable him to be sure of this fund in time, and to save his own surplus towards his own old age, after he had passed on what might be called the succession, to his children.

What, however, is the upshot of a 'survey' of the biological side of inheritance upon the economic aspects of inheritance of wealth without a more minute analysis of its trend ?

The more we survey the biological field the less do we find justification for inheritance of wealth by others than direct descendants or dependents. On the other hand, it does seem to me that we derive considerable support for the orthodox view that the power to make bequests in the direct line is an important economic factor in the accumulation of capital and in great personal effort. It does not, indeed, justify that kind of *inter vivos* giving which means the escape, almost on the death-bed, or within three years from it, from the Chancellor's net, but it *does* support the scheme of transmission of wealth in middle life as an economic factor of some importance, and a worthy use of accumulated wealth, which cannot be regarded as a net toll upon the community in view of its indirect contribution to the community. The argument, of course, spends its force as generations go on.

XII. Conclusions.

It will have been seen that the answers we have to the critical questions put at the outset vary in completeness and conclusiveness, and that in certain fields fruitful research is possible. Certain elements that have at one time been highly significant are now of less importance, while others are emerging.

My own present views, which, of course, are provisional in the sense that they are open to modification as new facts emerge and as analysis reveals tendencies not previously put into the balance, are as follows :—

1. In the past century unprecedented economic advance has been due in the main to the greater use of invention and fixed capital. This has, in turn, made new accumulation of savings possible, and has been made possible by the growing fund of accumulation. In this accumulation the principle of inheritance or bequest has played an important part. Where there has been freedom from the shackles of a family-diffusion system the greater progress has been possible. The individual motives which are operative under such a system are stronger than ever, but operate over a diminishing part of the field ; they are also stronger over a short period, and of diminishing effect over a long period of time. In other words, communal saving *via* company reserves (not subjected to the individual volition for saving against spending) and *via* repayment of debt through funds derived from taxation, and *via* large capital efforts (housing, &c.) partly financed through taxation, is an increasing proportion of the total. Although some of the values set up by such collective sums may figure in individual estate values, they are not created or destroyed by interference with, or promotion of, the right of inheritance.

2. The remaining considerable section of capital accumulation is still powerfully affected by inheritance rights, and would be more affected than heretofore by interference with rights in the direct line, though less affected than hitherto by rights out of that line. More considerable

changes might be made in the *width* of the rights than hitherto without seriously affecting accumulation. On the other hand, the time element is changing—accumulation is just as sensitive in the immediate provision and immediate rights of family enjoyment, but less sensitive to change (by restriction or encouragement) in the most remote rights.

3. The sense of 'social injustice' is directed against inequality of wealth, of which inequality through inheritance is not now the larger part. This sense, if limited to inheritance features, has less economic reaction than is generally supposed. In any case, it is a sense which is not scientifically based. I think it probable that, through the inequalities due to the system in which inheritance has a part, the average man has a slightly smaller *proportionate* share of the aggregate than he would have had if there had been no inheritance system, but a substantially larger *absolute* amount, because he shares a larger aggregate or better standard of life than he would have had under a system with no such aid to accumulation. Whether under these circumstances he is justified in having a sense of injustice, whether it is better for human welfare to have a low standard without envy, or a higher one with envy, is a matter lying beyond economics in the sphere of social psychology and philosophy.

4. The particular claims for unlimited rights of bequest, as settling the best economic direction and control, are gradually losing their force.

5. The principles upon which death duty taxation is at present based, though they may be the best available when administrative aspects are included, might be improved upon by closer regard to the foregoing analysis. The actual sum now being raised is not necessarily more harmful economically than a similar sum raised by additional income-tax, but it is more repressive in accumulation than the same sum would be if a less sum were raised at lower rates on the first succession and the balance were raised at higher rates on succeeding successions.[13]

[13] The practical aspects are discussed in the *Statistical Journal*, May 1926.

SECTION G.—ENGINEERING.

THE PRESENT AND FUTURE DEVELOPMENT OF ELECTRICITY SUPPLY.

ADDRESS BY

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PRESIDENT OF THE SECTION.

The rapid and almost universal development of electricity affords an example of the practical application of a great source of power in nature to the use and convenience of mankind with which there is no parallel. In telegraphy, telephony, telephotography, and especially in wireless telegraphy, the effects on humanity have been incalculable. Wireless telegraphy especially adds nowadays to the amenities of life, whether broadcasting world news, weather forecasts, music or educational addresses. It enables communication to be effected between, and the safe direction of, ships at sea in fog and all weathers, and the direction of aeroplanes and dirigibles in fog or at night, and it thus greatly lessens the risks of those who go down to the sea in ships or who travel by air.

The jubilee of the telephone was celebrated only a few weeks ago, and wireless telegraphy has come into prominence within recent years.

The aid to the surgeon and the electrical treatment of various diseases have enormously reduced human suffering; the investigations and researches of J. J. Thomson, Ernest Rutherford, and others have thrown a new and vivid light upon our conception of the structure of matter, and have aided the knowledge and researches of both the physicist and the chemist. Finally, in the almost universal application to all kinds of mechanical requirements—ranging from 100,000 kw. turbine generators or heavy freight locomotives at one end of the scale to motor-driven sewing-machines or vacuum cleaners at the other end—the advance it may simply be said has been remarkable.

Is there any other known form of energy which can be so readily and generally applied to large and small power, chemical and metallurgical processes, the production of light in various forms, or to all sorts of heating appliances, surgical and dental implements and laboratory instruments of the highest attainable degree of accuracy—in short, capable of almost universal application to all kinds of tools and transformation into various kinds of energy ?

The development of electricity supply as a necessary agent in the progress of civilisation has been accomplished within a very few years, for there was no general supply available in any part of the world prior

to 1889. Great Britain may be said to have been the pioneer of the public supply of electricity. The first legislation actually dates from 1882, but effectively only from 1888. An electrical supply industry has grown up in Great Britain by authorised undertakers (excluding railways and private plants), in which alone over £200,000,000 has been expended within the short period of thirty-seven years. In the earlier years distribution was confined to low-pressure direct current, with its necessarily restricted economic radius of supply, and to single-phase distribution at higher pressures for series arc lighting, applied in some districts to what was known as the 'house-to-house' system at pressures of 2,000 volts, and reduced by house transformers to the required service pressure.

It is interesting to note that at the present day, owing to the increasing difficulties of meeting the growing density of loads due to domestic requirements and the relatively high cost of L.T. distribution, there is a revival of the 'house-to-house' system where there are large blocks of buildings to be supplied. To such blocks of premises H.T. mains can be laid and transformers can be installed locally in order to reduce the street pressure to the low pressure required by consumers in the building itself.

The whole trend of development in this country was then towards the adoption of small local government areas as the areas of electricity supply, fostered largely by the technical restrictions brought about by the imperfect systems then available. The scientific world was divided into two camps—one favouring direct current, which has the advantage of using accumulators or storage batteries, and the other declaring in favour of alternating current. At that time only carbon-filament lamps were available, the single-phase alternating motor had not been perfected, and multi-phase currents were commercially unknown. Electricity was supplied mainly for lighting purposes, with a consequent low load factor. Hence very numerous independent systems of small size grew up, with the result that numerous private generating stations were installed in local factories and the larger workshops.

Individual development rather than collective effort was encouraged, and was, indeed, probably the only way at that time along which progress could have been made. The whole art of electricity generation and supply was also undergoing rapid development, and was the subject of numerous experiments by many designers, some of whom adopted 100 cycles for their alternating-current systems, others 93, 90, 87.5, 85, 83.5, 80, down to 25 or $16\frac{2}{3}$ cycles, so that a chaotic condition followed, made worse by a want of agreement between the engineers engaged on the work as to the most effective pressures of supply.

Distribution systems were gradually evolved from a simple 2-wire system, which, due to the influence of Hopkinson, became a 3-wire system, greatly reducing the weight of conductor required for any given amount of energy distributed and also extending the economic radius of supply.

There were two instances of 5-wire distribution, in Manchester and St. Pancras, but these proved to be cumbersome and costly and were eventually changed back to the 3-wire systems.

Among one's earliest recollections is the change-over in Kensington, under that veteran Colonel Crompton, from 100 to 200 volts and from a 2-wire to a 3-wire system; and again under the late Prof. H. Robinson,

when he laid the St. Pancras 5-wire system; the space occupied under the streets over thirty years ago by electrical mains would not be available or allowable to-day.

An extension of the useful radius of direct-current supply was made in this city and came to be known as the Oxford system; this was applied to several other localities. Electricity was generated at 2,000 volts direct current, or thereabout, and transmitted to sub-stations in which motor generators reduced the pressure to that required for local distribution and service to consumers, thus enabling a wider radius to be supplied from the generating station.

In those days great benefits were derived from the engineering skill of Willans, whose high-speed single-acting engines were largely used in the power stations of that time, and later from the splendid double-acting high-speed engines built by Belliss & Morcom and other well-known makers of high-speed sets.

It was not uncommon then to construct non-condensing generating stations, largely owing to the low load factor of the system; the consumption of coal per unit generated was correspondingly great and wasteful.

It is interesting to note how far we have progressed by comparing the ideal put forward by Colonel Crompton thirty-two years ago with present-day results.

The ideal cost of production was then placed at 1.32*d.*, excluding capital charges, and the average price to the consumers 3*d.* It is true that the load factor was only 20 per cent. and the capital outlay then as much as £125 per kw.i. At the present time the average revenue from all classes of consumer is 1.75*d.*—the average station load factor 29 per cent. and the capital outlay £52 per kw.

Far too little credit has been given to the pioneer work of Dr. Ferranti, who was the first to advocate generation on a large scale and transmission by high pressure over an extensive area of supply. It was he, in fact, who initiated this system at Deptford, necessarily limited to single-phase current in those early years. The principles now generally accepted were enunciated by him many years ago.

Then came the revolutionary discovery of the practical application of multi-phase currents, with all the attendant advantages arising from simpler construction of machinery, easy transformation by means of static apparatus, efficient long-distance transmission and facile application to appliances for lighting, power, or heat. This immensely widened the economic area of supply, and when a little later that illustrious pioneer, Sir Charles Parsons, after persistent and indefatigable research from 1884 onwards, at length overcame his initial difficulties, and about the year 1892 gave the electricity industry the steam turbine, so peculiarly fitted to the driving of 3-phase generators, electrical engineers at last possessed an equipment which enabled them to revolutionise the methods adopted in former years. Thereafter, all important power stations gradually changed over from reciprocating engines to the steam turbine, with its enormous gain in higher revolutions per minute, a factor of so fundamental an importance in the design and cost of modern electric generators. At the present time, reciprocating-engine sets represent only 8 per cent. of the total prime movers employed in public power stations, and their proportion is

decreasing each year. From speeds of 500 to 600 r.p.m. there was a stride to 1,500, 2,400, or 3,000 r.p.m., according to the frequency of system and size of generator. There was almost immediately a significant improvement in the machinery constructed for electric-supply purposes.

In 1898 an important inquiry was conducted by a Committee, under the chairmanship of Lord Cross, from whose Report sprang the power companies which now operate in most of our industrial districts, and whose areas of supply extend over whole counties and in some cases over several county areas.

There had thus been growing up not only a constant increase in the size and output of the generating stations, but constant increases in the pressures adopted for transmission brought about an ever-widening radius of supply and enlargement of the area served.

To-day we find a rapidly increasing growth of output, a decreasing cost and consequent widening circles of application ; and as in due season the industry simplifies its position still further by adopting one standard frequency and by reducing the number of supply pressures to the minimum practicable, the demands for electricity in this densely populated country are bound to expand to a degree which is not yet visualised. An attempt is made hereafter to envisage this growth of demand.

An important result follows from widening an area of distribution—it enables supplies to be given from a common source to many industries, to railways and tramways, and all kinds of domestic and trade requirements. It is found by investigation that the maximum requirements of the various classes of consumer do not coincide in point of time, and, speaking generally, if all their maximum demands occurred simultaneously, no less than from 2½ to 3 times the generating plant would be necessary to meet the load than is the case when their several supplies are drawn from one common source of generation. It is, in fact, only by supplying all the needs of a community within a large area from one common system that the maximum use can be made of the capital employed.

When one remembers that the annual capital charges on a generating station represent some two-fifths of the total cost of generation, it will be seen how important it is to obtain the greatest user of the plant installed. In fact, the combination of all requirements of a community, whether for domestic purposes, traction or industrial power, is a fundamental condition of economy in the public supply of electricity.

The 'load factor,' an expression for which the industry was indebted to Colonel Crompton at an early date in its history, is therefore a very important matter. It may shortly be defined as the ratio of the electrical energy actually produced by any generating plant in any period of time to the amount which would have been produced had that plant been working at full load continuously during that time. A kilowatt of plant working continually throughout a year (which is not a leap year !) will produce 8,760 units or kilowatt hours.

Now the *average* yearly load factor (on units *sold* by undertakings) throughout Great Britain to-day is under 25 per cent.—that is to say, the aggregate kilowatts required to meet the individual demands for hundreds of systems only produce one-quarter of the units possible were the plant working continuously.

No doubt the intrinsic load factor is really higher—by which is meant that could all these numerous undertakings be supplied from one common source, the resulting load factor on the generating plant would be found to be higher in value.

Still the fact remains that the capital expenditure on generating plant is four times what it would be were the load factor 100 per cent. The latter condition is of course not attainable, but something much better than 25 per cent. can certainly be obtained, an improved load factor on his system being the objective of every responsible engineer.

A small undertaking supplying a district mainly for lighting purposes will have only a low load factor, probably some 15 per cent. or less. If the consumers add other domestic requirements to their demands for lighting, such as heating rooms, cooking, and many small domestic appliances, it is found in practice that there is a great diversity among the times when the maximum loads of individual consumers occur.

Some observations made on the use of electric ranges, for example, reveal a diversity factor as high as eight, or in other words the maximum coincident load is only one-eighth of what would be recorded if all the apparatus were working fully at the same time.

A recorder chart which was taken by the Glasgow Corporation and published in Prof. S. Parker Smith's paper read before the Institution of Electrical Engineers in December 1925, shows that the daily load factor is 44 per cent. in the author's all-electric house, taking the maximum load as the continuous half-hourly maximum consumption. In this case 36 per cent. of the total units consumed are used at night for heating water on the storage system, and a general adoption of this arrangement would materially improve the load factor on the distribution system as well as on the generating station.

A very complete investigation was made a few years ago in a large southern residential district, which revealed the fact that the maximum demand on the power station followed the growth of lighting connections almost directly, and did not increase proportionately to the total connections of heating and lighting. In other words, the connections for heating had not noticeably affected the maximum load on the station. There was, in fact, a high diversity factor. That is material in the economics of electricity supply, for it meant in that particular case that no appreciable addition to the generating plant or capital involved in generation was necessary in order to supply the heating load, though a heavier outlay on distributing mains was necessarily incurred.

This increased service raised the load factor, which was stated to be 15 per cent. or less for lighting alone, to 30 per cent. or more with the comparatively limited application for heating and cooking at the time of the investigation referred to. That improvement refers only to one district. Consider further the combination of this district with another where the customs of the residents are somewhat different, such as their hours for meals, and an improved diversity would then be found.

If we go further and bring in industrial power loads, large and small, a yet higher load factor will generally be realised, albeit some industries *per se* have only a small load factor; but again their maximum requirements do not coincide. There are industries such as coal-mining where

the pumping and ventilating loads are almost continuous, and the load factor of which is therefore very high, and chemical or metallurgical works where processes are almost continuous. Other industries record a much smaller load factor, corresponding to the length of their working day. Combination of these various classes of industrial load again raises the general load factor. At the present time certain undertakings in this country which are supplying a wide range of industrial loads from a common source are enjoying load factors ranging from 40 to 50 per cent. Were domestic requirements to be expanded greatly and added to these industrial loads, the resultant load factor would be further raised in value.

Finally, there is the railway traction load, which must inevitably grow to large dimensions. The load factors of generating stations supplying railway demands are found to have values of 40 and 50 per cent.

If all these classes of demand can be met from a common source of supply, the general load factor can be raised to a maximum value. The result is to reduce the capital expended on generation to a minimum value. This has been done on a wide scale in this country on the north-east coast, where a supply over a wide area of approximately 1,400 square miles has been afforded for many years past by three or four principal generating stations supplemented by seven smaller waste-heat stations interconnected by trunk transmission lines. The annual load factor is not far short of 50 per cent., and the average costs of electricity supplied are very low; a large proportion of the output being delivered, of course, in the form of high-pressure 3-phase energy.

At the present time the amount of electricity generated in Great Britain, omitting privately-owned generating stations, amounts to about 7,000,000,000 units annually, of which 5,069,000,000 are sold by authorised undertakers, the balance being required for railway and tramway traction purposes.

It is found that in the four years 1921–2 to 1924–5 the average rate of growth has been exactly 20 per cent. per annum, the growth of output for power having been 25.3 per cent., domestic supplies 27 per cent., and traction 12 per cent. per annum respectively.

In recent Government publications it has been estimated that the output in Great Britain within the next fifteen years may reach a total of 21,000,000,000 units, or an even higher figure if electricity systems fulfil the requirements of a more extensive railway electrification. Let us see what are the possibilities of future development. While it may be unwise to predict an estimate of future demands, it is at least wise to endeavour to make some survey of possible extensions, however extravagant the results may seem at the moment. This survey enables us to have some vision of the extent of development and to plan the engineering system and methods of distribution in an economic and co-ordinated manner, while paying due regard to the more immediate needs. In other words, to be able to plan boldly but without prejudicing practical judgment by the adoption of a too extravagant immediate outlook.

An exhaustive survey has recently been completed by an influential committee of the National Electric Light Association relating to nine of the United States of America, and the Report of this survey ought to be read carefully by all who are interested in assisting a wide and wise

electrical development in this country. It is interesting to quote a paragraph from this masterly Report, which is as follows :—

> 'The futility of trying to forecast the development in time-steps of a few years was early recognised, and some definite time, not too near nor yet too far distant, had to be selected for the forecast. The year 1950 was chosen for this purpose and the estimates are based on that time. . . . It may be thought that the conditions for 1930 or even 1940 could be forecast with more certainty, and probably they could. However, the year itself is of no importance, but the approximate correctness of the picture is. If the development here assumed for 1950 is actually reached by 1945 or not until 1955, this is of no importance whatever. *What is important is the direction that the development now should take so as to insure building best for the future, and for this the assumed* 1950 *picture should serve as a guide.*'

Let us now try to sketch the probable scope in this country—a theme which may be appropriate for such an occasion as this, as being of general as well as of scientific interest.

There are three classes of supply in which great extensions may reasonably be expected: (1) domestic supplies, (2) industrial power, and (3) railway electrification.

Let us first consider the possibility of an extended domestic supply. Statistics derived from actual records of several housing estates and other sources, where electricity has been extensively but not wholly employed for heating, cooking, and lighting, show that the consumption *per capita* is over 1,100 units per annum, or 5,500 units for each house.

When electricity is the sole agent and is used not only for the above-named purposes but also for heating water for baths and general domestic requirements, and for many minor but economic and necessary operations such as vacuum cleaning, irons, sewing-machines, many kinds of small domestic and table appliances, and in some cases electrical washers, wringers and driers, the consumption *per capita* rises to over 2,500 units (equivalent to 85.3 therms) per annum. The amount consumed appears to be largely a question of the price of electricity; the cost, reliability, and availability of domestic appliances and competition with other sources of heat such as gas or central heating by fuel.

The existence of a great gas industry would make it absurd to suggest that in the course of the next generation the requirements of the country for domestic purposes would rise to a figure represented by the multiplication of the population of the country by 2,500 units *per capita*, to which would be added the requirements for industrial power and traction.

The output of the gas-supply industry for the year 1924 was 256,891,922 thousand cubic feet. The actual value in therms is not recorded. On the assumption that the average calorific value of the gas supply was 500 B.Th.U. per cubic foot, then the total therms supplied amounted to 1,284,000,000, or 30 therms per head of population, the total population of Great Britain being taken at 43,000,000 (1921 Census). This output is thermally equivalent to 870 units of electricity *per capita*. This is not a strictly correct statement, for a proportion of the population has neither a supply of gas nor of electricity, and the consumption *per capita* by the population actually served is really higher than the figure given.

Taking all these factors into consideration, and assuming the population at the end of the next twenty-five years will have grown to 50 millions, and that the methods and extent of distribution have advanced and developed—coupled with a sensible reduction in the cost of appliances resulting from scientific and commercial improvement and greatly increased scale of manufacture—the total output for domestic requirements, including residential premises, shops, offices, and public places, may be estimated at not less than 20,000,000,000 units, with a maximum load of 8,000,000 kilowatts.

An interesting speculation may be made and some support afforded to the reasonableness of this estimate from the following figures :—

In 1924 the amount of raw coal used for domestic purposes was given in the annual report of the Secretary for Mines as 34,280,000 tons, being 19 per cent. of the total consumption of coal in Great Britain.

Observations by the Fuel Research Board have assessed the average thermal efficiency of open coal fires, allowing both for radiation and convection of heat, at $22\frac{1}{2}$ per cent. of the total heat contained in the coal consumed. If we assume that the average thermal value of the coal per lb. is 11,000 B.Th.U., an average which is probably lower than the real figure, this tonnage is equivalent to $190{,}048 \times 10^9$ B.Th.U.

The gas returns published by the Board of Trade show that the average increase in the output between 1913 and 1924 of all the gas undertakings in the United Kingdom was 2.2 per cent. per annum, based on the 1913 returns, and the annual increase expressed in therms (assuming an average calorific value of 500 B.Th.U. per cubic foot of gas) was 22.7×10^6 over that period.

The electricity returns record an average rate of increase in the sales of electricity during the same period of 25.8 per cent. per annum, being a yearly increase of 340,000,000 units, equivalent to 11.6×10^6 therms per annum. Now it has been stated by the Fuel Research Board (Technical Paper No. 12) that the radiation efficiency of modern gas fires is generally from 55 per cent. to 60 per cent., to which must be added about 10 per cent. for convection, as is usually claimed. The radiation efficiency of electric heaters ' varies according to type, but reaches as much as 70 per cent. . . . Whatever the radiation efficiency, however, the total efficiency is 100 per cent., the balance appearing as direct convection.'

In future years, through the public demand for effective means of preventing atmospheric pollution and reducing the smoke nuisance, for increased cleanliness of buildings and from other considerations of public health, we can imagine most of the coal now consumed in open grates and kitchen ranges to be replaced by gas or by electrical apparatus. Without making any allowance for increased population, it would be fair to assume that this substituted means of heating at the consumer's premises could be subdivided approximately in the ratio of the recorded increased annual sales of gas and electricity, paying due regard to the efficiency of utilisation in each case. On this basis consumers' heating requirements would be provided as to $22.7 \times 0.7 = 15.9$ parts by gas and as to $11.6 \times 1 = 11.6$ parts by electricity. The resultant annual sales of gas and electricity merely for the purposes of displacing the above-mentioned tonnage of domestic coal would then be :—

Gas, 1569.7×10^6 therms.
Electricity, 801.6×10^6 therms.

This will probably not be considered to be an unfair proportion of subdivision as between the gas and electrical undertakings.

The quantity of electrical units equivalent to the 801.6×10^6 therms apportioned to electrical undertakings is 23,500,000,000. This figure, to which must be added the present electrical output for lighting and heating, assists in confirming the estimated total output of 20,000,000,000 referred to in previous paragraphs.

Unfortunately we have no idea at the moment of the total h.p. of machinery employed in the many industrial trades of the country. The last Census of Production dates back to 1907, and is obviously completely out of date. Details are known, however, of the total machinery installed in some of the industrial districts, which reveal the fact that the proportion of private electrical generating plant to public utility plant in those districts is 14 : 9; that is to say, that there is in those districts 55 per cent. more electrical plant privately owned. This survey, moreover, does not account for steam or other machinery unconnected with electric generators. In the Interim Report of Lord Haldane's Coal Conservation Sub-Committee, published in 1917 (Cd. 8880), an interesting table was taken from the Census of Production showing the average net output per employee in relation to the mechanical power employed in the factory. The table showed that when the net output per employee was between £50 and £75 per annum the h.p. employed (per 100 persons) was 67. The net output was increased to £125-£150 when the power used was 269 h.p., or £175 to £200 with 221 h.p. per hundred persons employed, according to the class of industry. Speaking generally, this may be expressed as an increase of earning capacity proportionate to the increased use of mechanical power. It is well known that in the U.S.A. the amount of power used is much greater per employee than in this country, and it was pointed out in the report referred to that in the U.S.A. the standard rates of wages were higher and the living conditions were better. Mr. John W. Lieb, the vice-president of the New York Edison Company, stated at last year's Conference on World Power, when discussing the social aspects of the greater development of power in industry, that the power used in productive industries in the U.S.A. increased from 2.14 h.p. to 3.24 h.p. per worker between 1899 and 1919. 'Taking forty-two industries, it is estimated that the actual value, measured in quantity of production added per worker to manufactured products, was increased by about 23 per cent., and in terms of money about two and a half times, despite shorter hours and less heavy labour. Increasing electrification is adding to the national prosperity and improving the conditions of the worker.' Mr. F. S. Low, the president of the American Society of Mechanical Engineers, also said: 'The workers are commencing to grasp another economic fact, that the more power there is used per workman the greater the workman's wages; and that in various districts, and in other countries, the rates of pay are in substantial proportion to the amount of power available to each productive hand.' In fact, Lord Haldane's sub-committee summed up the situation in the following words: 'The solution of the workman's problem, and also that of his employer, is the same, viz. the greatest

possible use of power. Hence the growing importance of having available an adequate and cheap supply of power produced with the greatest economy of fuel.'

Mr. D. Brownlie, in papers published in 'Engineering' in 1918–1920, recorded a survey made by him of the steam-raising plant in this country, and an analysis of the statistics collected by him showed that the coal used for the generation of steam in Great Britain for heat and power purposes at that time was between 75 and 100 million tons a year. He showed that the then existing boiler installations could be divided into three classes—bad, average, and highly efficient. The respective percentages were 10 per cent. bad, 85 per cent. average, and 5 per cent. highly efficient. It is clear, therefore, that there is scope for enormous economies, and, as practice is tending more and more to centralise, much of the power now provided locally by independent plants, 95 per cent. of which are only of average efficiency, including some which are really bad, will be gradually replaced by power electrically transmitted from central sources of generation. As the late Sir George Beilby said: 'The problem of the future which awaits solution is how to stimulate the practical interest of owners of steam-raising plant throughout the country. It may be that the permanently increased cost of coal will supply the necessary stimulus.' In the Coal Conservation Committee's Report (Appendix A) the estimated coal consumption for industries, excluding public utility plants, was given as 66,000,000 tons, made up as follows :—

Mining, 18,000,000 tons.

Iron and steel, engineering, textiles, chemicals, paper, and all other trades, 48,000,000 tons.

In the 1924 coal returns the coal-mines consumed 16.2 million tons, while general manufactures and all other purposes consumed 68.5 million tons, a total of 84.7 millions. It will be observed that the coal-mines have dropped their consumption, due no doubt to the installation of modern electrical machinery, such as we know that some of them possess.

Some of this coal is required for heating purposes by the textile trades, or in brewing, chemical trades, brick-making, bakeries, and so forth. If we deduct 25 per cent. for that purpose from the 68.5 millions, there remain 51.4 millions plus 16.2 millions used by coal-mines, or a total of 67.6 million tons of coal for which electrical power could be substituted.

Owing to the prevalence at that time of indifferently efficient steam-raising and power plant, it was stated in the Appendix to the Coal Conservation Report that approximately 8.03 lb. of coal per horse-power hour were consumed, which, if true, represented an appalling waste, being equivalent to no less than 10.76 lb. per kw.h. or electrical unit.

While so high a figure as 8.03 lb. may have been recorded at the time of the last Census of Production in 1907, advance must assuredly have been made in recent years. Making some allowance for this advance (though necessarily not too liberal an allowance having regard to Mr. Brownlie's figures for 1918–1920), we may reasonably assume a reduction from 8.03 lb. to 6 lb. per horse-power hour, which is equivalent to 8 lb. per electrical unit. From this it may be directly deduced that if all these power requirements could be supplied, as in all probability some day they

will be supplied, from electrical systems, the equivalent output would be 19,000,000,000 units per annum.

Now we know that the usual ratio of plant connected to electrical systems to the maximum load is 2.5 : 1, that the *average* industrial load factor is about 30 per cent., having regard to the variety of trades—the output from public generating stations for industrial power in 1924–5 was 3,556,000,000 units, and the rate of growth has been in recent years 25 per cent. per annum.

From all these data it may be fairly assumed that if the majority of our industrial works (omitting certain classes which require steam for particular processes) derived their supply from public systems of supply, and an increasing use of power per employee must also be assumed, we should expect a future output for industrial power of not less than 20,000,000,000 units with a maximum load of 9,200,000 kilowatts. There are certain well-equipped collieries which will probably continue to retain their own plant by reason of their high load factor, and the cheap small fuel which they consume with a consequent low cost of production. The large output from these collieries cannot be credited to the future output from public systems of supply.

There are possibilities of great expansion in railway electrification in this country. The present electrified systems, with the exception of the Shildon Branch Line in the County of Durham, are confined to suburban services. The largest development is that of the Southern Railway (Metropolitan Suburban) lines; the others being the London Electric Railways, the Metropolitan District Railway, London and North Eastern Railway (Tyneside), and the London Midland and Scottish Watford line, Lancaster-Heysham Branch, Liverpool-Southport and Manchester-Bury systems. The present output for railway traction is about 700,000,000 units, 615,000,000 units of which are generated at stations belonging to the railway companies, the remainder being purchased from general supply systems. A Committee of the Ministry of Transport reported within the last few years the desirability of standardising railway electrical systems so far as is practicable, having regard to what has already been put into operation. That Committee recommended that the supply for traction purposes should be generated in the form of 3-phase 50-cycle energy, and converted in the requisite sub-stations to direct current with a conductor pressure of 1,500 volts or a multiple (or sub-multiple) of that pressure. The Inner London systems have already adopted 600 volts D.C. extensively, and cannot be reconciled completely with a pressure of 750 volts, which would be the practical sub-multiple of the recommended standard. In the case of the A.C. 11,000-volt system—twenty-five cycles—in operation on that part of the Southern Suburban services originally known as the L.B. & S.C., a recent public statement of the chairman of that railway made it clear that a change to the D.C. system is being contemplated. In France the Government have adopted a standard of 1,500 volts D.C., and extensive systems in the Midi are now being electrified; other French railway systems will also be converted from steam to electric traction. In a recent report published by the British Government it was stated that calculations had been made by the Ministry of Transport of the total consumption by British railways were

the whole of the lines to be electrified. The result was a total of nearly 7,000,000,000 units, equivalent to an output of 160 units *per capita*—a figure almost identical with the railway consumption estimated in the survey of certain railways in some of the United States. At a load factor of 40 per cent., this output would represent a maximum demand of practically 2,000,000 kw.

Summarising these figures, the following total is obtained :—

	Units in Millions.	Kw.D.
Domestic, &c.	20,000	8,000,000
Industrial power	20,000	9,200,000
Railway traction only	7,000	2,000,000
Total	47,000	19,200,000

The aggregate maximum demand is 19,200,000 kw., but an allowance for some diversity should be made on this output of $47{,}000 \times 10^6$ units which would probably reduce the maximum demand to 15,500,000 kw., representing an annual load factor on the whole output of about 35 per cent.

This, then, is a reasonably possible output to be provided for at some future date—an expansion which can only be met by a much larger conception of the methods of generation and transmission than has hitherto been adopted. Such a figure may be criticised as being entirely visionary and quite unlikely of attainment—but is it really so ? Development has been accelerating during the last few years : improvements which are already being carried out will certainly have a further economic effect, and the whole trend of public requirements, domestic consumption, public health improvement, improved means of transport, better organisation of industry, and a greater use of power, with improved machine tools, are all tending to a greatly increased application of electricity as being the readiest agent for these purposes. This is a development which cannot be denied, and must not be overlooked by those entrusted with the design of the future electrical systems in this country.

The recent survey in nine of the United States before referred to showed that at the time of the survey 86 per cent. of the prime movers was steam-driven, only 13 per cent. was derived from water-power, and 10 per cent. from internal-combustion engines. The output from the steam plant was 83 per cent. of the whole, and from water-power about 15 per cent.

The rate of growth in five years—*i.e.* between 1917 and 1922—was 63 per cent., or an average of 12.6 per cent. per annum on the 1917 figures, which may be compared with the 20 per cent. annual increase in Great Britain.

The powerful and skilled Committee made this exhaustive survey with a view to regulating throughout that area the proper kind of development of so important an industry as electricity supply, which, in the United States, is considered so indispensable not only for industrial expansion but also for railway electrification and for general domestic purposes. This Committee endeavoured to envisage the output which may be expected in the year 1950, when the population of the area in question is estimated

to reach a total of 32,624,000 persons (Electric Power Survey made by Power Surveying Committee, National Electric Light Association, December 1, 1925).

The consumption in 1950 is estimated at 1,651 units *per capita*, or 1,924 units generated.

The subdivision is as follows, and is interesting :—

Railways	163	units *per capita*
Industrial power	833	,, ,,
Agricultural power and drainage	40	,, ,,
Domestic and business services	383	,, ,,
Public services, street lighting, sewage pumps, &c.	79	,, ,,
Other uses	153	,, ,,
Total	1,651	

While no exact parallel can be drawn between the consumption in this country and the U.S.A.—because the conditions are so different—it is nevertheless a modest estimate which only anticipates an average consumption in this country of 940 units *per capita*, as against 1,651 units estimated by a Committee of skilled investigators as the future requirements in the Central States of the great Republic.

Whether this estimate for Great Britain be exaggerated or not, it is certain that provision for a largely increased output will have to be made.

The sources of power available in this country are mainly coal and coke, but there are also inland and tidal water-power to a small extent, and some sources of waste heat. It is certain, however, that the bulk of this future electrical output must be produced in fuel-fired stations.

An investigation was made into the water-power resources of Great Britain by the Water Power Resources Committee appointed by the Board of Trade in 1918, whose final report was issued in 1921. Many watersheds were carefully examined by eminent Civil Engineers, and these indicated a capacity of some 275,000 kw. working continuously, being made up of 195,000 kw. in Scotland, 60,000 kw. in North and Mid Wales, and 20,000 kw. in England. Of this total it was then considered that 210,000 kw. could be economically developed. Since this report was issued, Parliamentary powers have already been granted for the Lochaber scheme (54,000 kw.), now in course of construction, the Grampians scheme (estimated to develop 80,000 kw.), and for small schemes of 7,000 kw. in Ayrshire at Loch Doon, and 12,000 kw. at the Falls of Clyde, now under construction by the Lanarkshire Hydro-Electric Power Company.

This Committee was careful to note that the figures quoted above relate only 'to certain specific water-power schemes, and that they by no means represent the total water-power resources of Great Britain.' Having regard to the average rainfall in North Wales and in Northern Scotland and the contours of those districts, it is almost certain that other economic sources of water-power would be revealed by a more extended survey. For the present purposes, and including the important existing works of the British Aluminium Company at Kinlochleven (23,000 kw. with an annual output of 173,000,000 units) and those of the North Wales

Power Company and the Aluminium Corporation in North Wales, it may be taken that at least 400,000 kw. (continuous rating) could be developed by inland water-power in Great Britain.

Suggestions and schemes have also been put forward for the development of tidal power, notably in the Severn Estuary; and the Water Power Resources Committee, after hearing evidence, reported that a *prima facie* case had been made out, and that more detailed investigation should be undertaken. A hydrographical survey is, in fact, now being conducted by the Government. Preliminary estimates of the power available—making allowance for secondary water storage at high elevation working supplementary turbines in order to level out the intermittency of the lunar cycle—show that approximately 260,000 kw. could be generated, equivalent to at least 1,000,000,000 units transmitted annually from this source. It is possible that tidal schemes in other situations may hereafter be deemed practicable; but in no part of Great Britain can such potentialities be found as in the Severn, not only because of the enormous volume of water flowing and ebbing in that estuary, but also because the physical configuration assists in producing a 47-foot rise at ordinary spring tides.

The utilisation of water-power for electrical generation and transmission is one of the finest and perhaps most fascinating ways of harnessing the great forces in nature for the use and convenience of man. It is a power which ought to be utilised as fully as possible in our country in the interests of true national wealth. It must not be overlooked that a well-constructed dam and works will last for centuries, that the wasting assets in the form of turbines and possible pipe-lines represent only a small proportion of the total expenditure. Moreover, of the total cost of electrical energy produced, no less than 85 to 90 per cent. represents capital charges. When the capital outlay on the permanent assets is redeemed the cost of energy is reduced to a very low figure indeed. This is a factor which is insufficiently appreciated in this country. Other countries which have been endowed with more liberal sources of water-power will for this reason benefit considerably a generation or two hence.

This is an additional reason for so laying our plans in this industrial country, where we must depend upon our industries—agricultural, engineering, shipbuilding, textiles, and others—in order to live and continue to exist as a great nation. It is essential that abundant power shall be available in all necessary parts of the country. The bulk of this power, as has been said, must be derived from coal.

There is no known method of storing electricity on a very large scale, and thus consideration must be given to the most economical means of coping with the public demand from hour to hour, or even minute to minute. If anyone will look at a 24-hour load-curve recorded at any electricity station, a considerable variation in the height of the curve will be noted at various times of the day or year according to the demand for power, heating, traction, or lighting. But it will also be seen that if a line be drawn through the curve parallel to the base, at a point some two-fifths of the highest ordinate, all below that line represents an almost uniform output all the year round, excepting week-ends and holidays; in other words, there is a *base load* of very high value, representing generally an annual load factor of 50 or 60 per cent. The remainder of the curve,

according to the time and season, is less regular and more intermittent. If we take as example the estimated total requirements at some future day—namely, the 15,500,000 kw. and 47,000,000,000 units output—the base load would represent a load of 6,000,000 kw., the output of which would be 30,000,000,000 units or thereabout, while the remaining 9,500,000 kw. would produce the balance of the output, viz. 17,000,000,000 units, at the low annual load factor of 20 per cent. or thereabout. It is a fundamental requirement in the economics of electricity supply that the base load or high load factor component of the total output must be generated at the most economical rate that engineers can devise. What are the lines along which improvements are now being made to convert the highest possible thermal units available in the fuel consumed into useful work for the benefit of the consumer ?

The published Analyses and Summaries of Returns of fuel consumption show that the average thermal efficiency of 1924–25 for all public generating stations in this country was as low as 12.45 per cent. with an average station load factor of 28.84 per cent. The highest recorded efficiency for that year was at the Barton Station of the Corporation of Manchester, viz. 19.85 per cent. based on units generated, the station working at an average annual load factor of only 29.5 per cent. Corresponding figures for the year 1925–26 show that the average thermal efficiency has been raised to 21.48 per cent.—equivalent to 20.40 per cent. based on units of ‘ output ’—with an annual station load factor of 48 per cent.

From a paper recently presented to the Mid West Power Conference in Chicago by Mr. Wm. S. Monroe, it would appear that the Crawford Avenue Station of the Commonwealth Edison Company of Chicago has recorded a thermal efficiency based on ‘ output ’ of 22.24 per cent., working at a station load factor of between 60 and 70 per cent. It is understood that the plant at this station is not yet in full operation, and therefore higher operating efficiencies may be anticipated.

The steam pressure at Barton is 375 lb. per square inch, and at Crawford Avenue 550 lb. In the former case the condensing water is drawn from the Ship Canal, which has its limitations, while the Crawford Avenue Station draws its condensing water from Lake Michigan, where the volume is relatively inexhaustible and the average annual temperature is low. A higher average percentage vacuum is therefore probable at the latter station, assisting towards higher thermal efficiency.

The published results of other American stations—notably at Philo and Boston—would appear to indicate that thermal efficiencies of the order of 24 per cent. have been obtained.

Let us examine, first, the improvements which are being tested in practice to turn into useful work the highest amount of the heat available in fuel, and then consider their commercial value; having regard to the capital invested. If we take a modern station as an example, working at an annual load factor of 40 to 50 per cent., the total costs of generation may be subdivided as follows :—

Coal	46	per cent. of the total generating costs
Capital charges ..	40	,, ,, ,, ,,
Other costs	14	,, ,, ,, ,,
	100	per cent.

The two principal items in which economies must be sought are obviously a reduction in the consumption of coal per unit generated, and a reduction in the capital expenditure.

Many refinements can be employed which may economise coal, but at the expense of an undue capital expenditure. Broadly speaking, the employment of bigger stations and an increase in the size of plant employed reduces the capital employed per kw. of plant installed. Interconnection of stations further reduces the percentage of reserve plant, and thus reduces the capital employed per kw. of plant demanded.

The employment of higher steam-pressures, reheating the steam in the later turbine stages, so as to reduce its total volume and minimise the difficulties of design experienced in the vacuum stages of the turbine, stage feed-water heating through 'bleeding' the turbine, and thus utilising the latent heat in the steam, are all producing higher thermal efficiencies between the electricity generated and the fuel consumed.

Sir Charles Parsons, to whom the world owes so much, has shown that with a steam-pressure of 500 lb. per square inch and a 97.5 per cent. vacuum we may hope to reach a full-load thermal efficiency (steam to electricity) of $33\frac{1}{2}$ per cent., while with an initial steam-pressure of 1,000 lb. per square inch we may obtain a thermal efficiency of 35 per cent.

Assuming a boiler-plant efficiency of 83 per cent., the equivalent efficiencies (fuel to electricity) are 27.97 per cent. at 500 lb. pressure, and 29.2 per cent. at 1,000 lb., which are figures comparable with the best realised results claimed from internal-combustion engines. The equivalent heat consumptions per kw.h. are 12,200 and 11,685 B.Th.U. respectively, or, assuming coal as fired to have a value of 11,500 B.Th.U. per lb., the coal consumed is 1.16 lb. and 1.11 lb. per kw.h.

The development and steady improvement of the steam-using plant at the generating station is proceeding satisfactorily, and we are certainly within sight of a heat consumption not exceeding 12,000 B.Th.U. per kw.h. generated at base-load stations. Where a group of stations is interconnected the peak-load stations with annual load factors of only about 20 per cent. would, *cæteris paribus*, require a fuel consumption of about 20,000 B.Th.U. per kw.h. generated. Although the annual load factor is low, the programme for running the plant can be so arranged that the plant load factor is high. There is a probability that fewer refinements would be commercially justified in peak-load stations, and in the estimates which follow the heat consumption at such stations is advisedly taken at 22,000 B.Th.U. per unit generated. The average B.Th.U. per unit sent out or available for transmission would thus be 16,500, at a station load factor of 35 per cent., and representing a thermal efficiency all round of 20.6 per cent., which would be a notable advance on the last recorded figure of 12.45 per cent. for the whole country.

There is also the steam-raising plant to be considered, and it may be well to review briefly the economic developments which may be looked for.

With the coming of the larger turbine, a demand has arisen for larger boiler units and higher evaporative capacities. The present general land practice is some 7 to 8 lb. of water evaporated per square foot of heating surface, but in marine practice, and in naval practice particularly, evaporations up to 20 lb. per square foot are normally called for.

Boilers are already in commission with an evaporative duty of 300,000 lb. per hour. For pressures of 800 lb. and over it is necessary to avoid riveting and to adopt a seamless drum. With high evaporative duty per square foot of heating surface, the de-aeration of the feed water becomes of great importance, in order to avoid rapid corrosion of the tubes, and in modern types especially, where pulverised fuel is used, the combustion chamber is practically lined with tubes, so as to obtain as large a tube surface as possible exposed to direct radiation.

The tendency in boiler design for large power stations is unquestionably towards higher evaporative capacities, larger boiler units, and higher steam-pressures.

The use of pulverised fuel appears to lend itself to these modern requirements in capital stations, enabling better control to be exercised, a higher thermal efficiency to be obtained, and less wear and tear of plant, a better distribution of heat in the boiler, and therefore a better evaporation.

It is reported that at the Lake Shore Station, Cleveland, U.S.A., boilers of 30,000 square feet heating surface and fed with pulverised fuel are maintaining an average efficiency of 90.4 per cent.

The utilisation of pulverised fuel also raises a larger question. Not only is there a possibility of commercially utilising the waste from coal-mines, but it would appear to bring within the ambit of possibility a combination of some form of low-temperature carbonisation of the fuel, so as to enable some of the valuable by-products to be recovered, coupled with the production of a soft coke which can be applied in a pulverised form to the boilers for steam-raising purposes.

A practical application is now being made of the McEwen-Runge low-temperature carbonisation plant to the Lakeside Power Station of the Milwaukee Electric Railways and Light Company, Wisconsin, U.S.A., the result of which will be awaited with interest, and if satisfactory should be of great value to designers of future base-load stations.

Suggestions have been made that gas and electricity undertakings should be combined for the purpose of conserving fuel. It is significant that although a large number of local authorities in Great Britain have owned both gas and electricity undertakings for many years past, there is no single instance of any such authority having effected a complete amalgamation of its undertakings. There are a few cases where companies operate gas undertakings in conjunction with electricity-supply undertakings, but their total plant capacity is very small, and represents only 0.1 per cent. of all the generating plant installed by authorised undertakers in the country.

There can be no advantage to a gas undertaking unless the price at which the gas or coke can be supplied to the power station shows a margin over the costs incurred in producing the gas or coke; nor is there an advantage to the electricity undertaking unless the price paid for the coke or gaseous fuel on an effective heat-value basis is at the best not greater than the cost at which raw coal of equivalent heat value can be purchased.

The average price paid for coal by electricity undertakings between 1922 and 1924 was approximately 20*s*. per ton. If we assume the average calorific value as being 10,500 B.Th.U. per lb., there would be no economic

advantage to the power station unless the gaseous fuel could be purchased in the necessary quantity at 1.02*d.* per therm delivered to the power station, which is equivalent to 5.1*d.* per 1,000 cubic feet of gas, having a calorific value of 500 B.Th.U. per cubic foot.

Nor does it appear that coke obtained from ordinary gasworks practice can be commercially applied on a large scale to capital power stations. There would, of course, be an advantage to the gas industry if a regular and stable market for their principal by-product were thus procured. In 1924 the principal gasworks of the country produced 14.2 cwt. (gross) of coke per ton of coal consumed—before deducting the amount of coke used for water-gas and for the carbonising plant—the net amount per ton of coal being generally about 10.3 cwt. of coke. The receipts from the sale of coke represented (in the principal gas undertakings) some 19 per cent. of the total income of those undertakings, the average price received having been 27*s.* 2*d.* per ton, which was a higher price than that of the coal used by electricity undertakings at equivalent thermal values. There is, it must be remembered, a wider scope in the classes of coal which can be purchased by electricity undertakings than is the case with gasworks. The fact that in 1924 the average price paid by electricity works for coal was 20*s.* per ton, and the average price paid by gas undertakings which only produce coal-gas was upwards of 27*s.* per ton, cannot be ignored, though the latter was of course of a higher thermal quality, containing more volatiles and probably a less ash content. Gas-works coke has a higher ash content and is less easily ignited than coal, and so far has had only an exceedingly limited outlet as power-station fuel in this country, the amount, in fact, being about 1 per cent. of the total coke and breeze available for disposal by the gas industry, and being less than $1\frac{1}{2}$ per cent. of the raw coal consumed in the generation of electricity in public-utility stations. It lies with the gas industry to show whether they can supply heat to future large power stations in the large volumes necessary in modern practice, at rates which would be no greater than the equivalent cost of raw coal, and in forms which will be as efficient in application to boilers of large evaporative capacity. If they can do so, then assuredly electricity undertakings should in the national interest give the fullest consideration to such a proposal.

In the case of low-temperature carbonisation it is obvious that more coal must be consumed for any given heat requirements at a power station. Various technical problems still remain to be solved, and reliable commercial data both as to capital and operating costs still remain to be established. The application to a definite purpose, such as steam-raising in a base-load power station, would, of course, minimise any commercial uncertainty, for there would be a definite purchaser of the heat products, while the other marketable products would be limited to the crude fuel oils, for which a sale could probably always be found.

As Dr. C. H. Lander and Mr. R. T. McKay have pointed out, the yield of coke (with a calorific value of about 12,500 B.Th.U. per lb.) per ton of coal from straight low-temperature carbonisation processes averages 14 cwt., and ‘ therefore the value of the liquid and gaseous products must be sufficient to yield a profit after paying the entire costs of retorting and the costs of about 6 cwt. of the raw coal treated.’

The late Sir George Beilby, in his James Forrest Lecture at the Institution of Civil Engineers in 1921, said: 'When coal is used for steam-raising under the best known conditions, it is obvious there is little to be gained in thermal efficiency by any preliminary sorting out of the thermal units of the coal into fuels of higher availability. It is well known that an efficiency of 75 to 80 per cent. is attainable in steady practice,' and he went on to quote the results from two power stations—namely, the Central Electric Supply Company at St. John's Wood, where the average boiler efficiency was 75.5 per cent. although the average ash content in the coal fired was 18.4 per cent., and the Southern Railway Company's power station at Wimbledon, where the average boiler efficiency was 78 per cent. with an ash content of 16 per cent.

Sir George Beilby also said: 'Supposing the coal used at these stations had been submitted for preliminary carbonisation and its thermal units sorted out into the forms of gas, tar, and coke, how would this have affected the evaporative capacity? Of the thermal units of coal

		Per Cent.
The coke would contain		70
The gas " "		12
The oils " "		11
		93
	Per Cent.	
Intrinsic thermal loss	7	
Heat for carbonisation	6	
		13
Net thermal value		80

'The high thermal availability of the rich gas would be thrown away if it were used for steam-raising, the fuel oil would be a boiler fuel decidedly superior to the original coal, and the coke would not be of more than equal value to the coal. Solely from a steam-raising point of view, therefore, a thermal loss and not a gain would result from the operation. I am quite prepared to admit that in special cases this thermal loss might be compensated for if a local market for the rich gas were available. In most cases, however, the margin of profit would be much too small to justify the extra capital expenditure which would be required.'

The additional capital cost of low-temperature carbonisation plant appears to be from £0.9 to £1.1 per ton of coal carbonised, which is equivalent to £4 per kw.i. additional capital expended, or 28 per cent. addition to the normal capital expended upon a modern power station. It has been claimed that, after allowance for the extra capital charges on the station and crediting the cost of production with the marketable value of the fuel oils recovered by the process, the net cost of electrical energy delivered (not only the net cost of the fuel consumed) would be reduced by more than 50 per cent. One may be sceptical about the realisation of so great an improvement, but until the matter has been put thoroughly to the test it is impossible to say whether this method of treating coal will really be a source of economy in the generation of electricity.

Whatever the future may bring forth in the application of coal

carbonisation to large power stations, it is clear that developments are taking place which will bring about a substantial reduction in the cost of generating electricity and effect a more scientific utilisation of our natural fuel resources.

There can be little doubt about the modern tendency to concentrate the points at which electricity can be generated and made available for general distribution and consumption, whether it be for railway traction, power stations taking the place of the individual locomotives; or in large industrial plants where a public system of generation and distribution of electricity takes the place of individual generating plant at the local works; or in domestic requirements for heating and other purposes in place of the open coal fire. All of these measures assist in preventing a wasteful expenditure of coal. It is clear, therefore, that any system which can recover the greatest amount of the stored energy available in coal should be fully explored, and it is the large power station of 200,000 kw. and upwards that would appear to offer a means of investigating the value of new fuel processes on a practical scale.

There has been a far too prodigal use of coal in the past and more scientific methods for its utilisation are urgently wanted. There is all the waste of small coal at the pits to be dealt with, and there is this question of the more perfect utilisation of the coal which is consumed. Having regard to the recommendations of the recent Royal Commission on Coal and to the very real need for national economy in the present and succeeding generations, any improved method which will either turn into useful work the highest heat units or obtain the utmost commercial value of the raw coal consumed must be fully and practically explored.

There seems little doubt we may expect that within a few years electricity will be generated at modern power stations even with direct firing at a figure of 0.3*d.* or less per unit. This will be transmitted at high pressures for such purposes as railway traction, large blocks of industrial power, and supplies in bulk to local undertakers, who in turn will retail it to their consumers. This involves the construction of high-tension transmission lines or cables and the provision of transformers and switchgear. Broadly speaking, transmission costs would add 10 per cent. to the cost of the units sent out from the power stations, assuming a reasonable average load factor. So we can hope to transmit energy in quantity and transform it locally to the required service pressure at a cost of 0.33*d.* or less per unit sent out when applied at an average load factor of say 33 per cent. This cost of bulk supplies is equivalent to about 0.4*d.* per unit transmitted and delivered by means of H.T. mains, and transformed locally to the requisite pressure.

In Great Britain it will probably not be possible to make use of overhead lines to the same extent as is possible in the U.S.A. and some other countries. The advantage of overhead lines lies in the ability to use the highest pressures and in their smaller cost compared with underground cables. For equal losses the cost of cable transmission of large carrying capacity, and working at the comparatively low pressures of 33,000 and 66,000 volts, is proportionate to the cost of overhead lines working at like pressures as 2.5 : 1 and 2 : 1 respectively.

The highest working pressure on 3-core cables so far applied in practice has been 66,000 volts between phases or 37,500 volts phase to earth. The construction of 3-core cables for large power transmission, *i.e.* with conductors of 0.25 square inch, for example, offers great difficulties of both an electrical and mechanical nature. Moreover, the short lengths in which such heavy cables can only be constructed entail the use of numerous joint boxes.

It would seem that future practice in cable transmission at the higher pressures must tend towards the adoption of single-core cables which can be manufactured in greater lengths and with greater facilities in the factory. These have the benefit of simpler jointing and are more easily handled in the road. Single-core cables are now being constructed with a pressure of 132,000 volts between phases or 76,000 volts to earth, and cable manufacturers are confident that such cables can be applied with safety.

It is the cost of local distribution which causes a considerable addition to be made to the cost of generation and transmission, and in which economies must also be made possible in future extensions. As the published official statistics show, the present average capital expended on distribution systems in Great Britain is £21 per 1,000 units sold, including the cost of sub-stations ; in numerous cases rotary converter sub-stations are included, the cost of which is some seven to eight times that of static transformer stations. The actual cost, for example, in Glasgow is £15.96 per kw.i. for rotary sub-stations and only £1.822 per kw.i. for static sub-stations ; the ratio of costs in this case being 8.76 : 1. If one compares the operating costs, including capital charges on the sub-station, the rotary sub-stations required 0.1926*d.* per unit sold, as against only 0.0334*d.* in the static sub-stations—in other words, the rotary sub-station expenses are nearly six times those of the static sub-stations per unit sold.

In a large English city where A.C. distribution has been exclusively adopted (excepting the supply to the local tramway system), the capital outlay on distribution, including H.T. feeders and sub-stations, L.T. mains services and meters, is actually reduced to £13.48 per 1,000 units sold. The future cost where A.C. distribution is exclusively used is estimated at £11.25 per 1,000 units sold.

In ordinary town-distribution systems the capital cost depends upon the number of consumers obtained per mile of main laid.

The conditions of domestic electric services and loads are changing so rapidly that it requires considerable judgment on the part of the engineer to lay out a distribution system with a due regard to a reasonable balance between future requirements and the immediate outlay.

It is not unreasonable to assume that future capital investment in distribution will not exceed £11 or £12 per 1,000 units sold, since the bulk of future distribution will be by means of alternating current and the simpler static transformer sub-stations.

Assuming that the average price of coal (of 10,500 B.Th.U. value) delivered to the generating stations throughout the country is 20*s.* per ton, it is safe to say that the *average* price at which electricity should be available within a few years should be under $\frac{9}{10}$ths of one penny per unit.

This may be expressed in the following terms when applied to various classes of consumer:—

A.C. energy transmitted in bulk to large consumers, such as railways and large industries	From 0.5*d.* to 0.25*d.* per unit, according to increasing load factor.
A.C. energy distributed locally for general domestic purposes, including lighting	About 0.8*d.* per unit.
Lighting only	About 2*d.* per unit.
Small power supplies	About 1.25*d.* per unit.

As was previously mentioned, energy in bulk and supplied after simple transformation directly from the high-pressure transmission system can then be sold for an average of 0.4 penny. It is the capital expenditure thereafter on local distribution systems and their operating costs which raise the price to the local consumer. In the figures referred to it will be noted that the average cost of low-tension energy after distribution is $2\frac{1}{4}$ times the average cost of energy requiring only high-pressure transmission lines. And when one speaks of an average cost of $\frac{9}{10}$ths of a penny, even after this cost of local distribution is included, it must be remembered that local costs of distribution differ widely at the present time, due mainly to the differing densities of load and load factor and number of consumers served per unit length of main laid. Therefore, although it will be possible hereafter to supply electricity for lighting purposes at an *average* cost of 2*d.*, it is certain that sparser districts will have to pay more owing to the incidence of the capital expended on local distribution, unless a much greater freedom is allowed in the use of overhead lines. One cannot readily understand the great objection raised to the use of such lines if they be properly designed and erected. They are far less obtrusive than the ordinary telephone and telegraph lines which are now so ubiquitous. Light steel taper poles painted to suit their environment are barely noticeable, and in many places bracket attachments can be made to buildings. Without entering into too much detail, it is enough to say that local distribution systems in villages can be installed at a quite small expenditure, and local communities must assist in this matter if they desire to obtain the benefit of a cheap electrical service at an early date.

What prospect is there of electricity helping what is, after all, our greatest industry—agriculture? For it must not be forgotten that half of the area of the country is farm-land, and that there are nearly 500,000 farms in Great Britain. For several years past it has been a matter of great interest to preside over a Committee appointed by the Minister of Agriculture and Fisheries, the purpose of the Committee being to investigate the application of electrical discharge to the growth and yield of crops. Under the patient and skilled investigation of Prof. V. H. Blackman, assisted by that great authority Sir E. J. Russell, experimental work has now been conducted at Rothamsted and at Lincluden for several years, with variable but on the whole definitely encouraging results.

For the time being work is concentrated on scientific pot-culture and small-plot observations, but it is hoped soon to resume field experiments on a wider and practical scale. While the future may reveal a way by which electricity can be used directly to stimulate growth and improve

the yield of cereals and other crops on a definitely practical and commercial basis, for the present it is in the application of power to the farm and the provision of better and more convenient lighting of the farmstead to which we must look for affording immediate assistance to the farmer. It is doubtful whether electricity will be used to any marked degree in this country for field operations such as ploughing or reaping, partly owing to the small area of the average holdings and to the prevalence of hedges and comparatively small fields which are so essentially an English institution. In some of the larger holdings, however, as in the eastern counties of England or in southern Scotland, it is probable that electricity will be used in field operations, as is the case in other countries, more especially in Scandinavia and some parts of Germany and Canada. In Sweden, for instance, there are 52,000 farms, representing 40 per cent. of the arable land, which have the advantages arising from an electrical service. It is interesting to note that the average consumption is 53 units per acre, and the individual load factor is only about 15 per cent. It is stated that the consumption by these farms is one-twentieth of the total electricity supplied, and is equal in amount to the aggregate consumption for lighting and domestic purposes in the Swedish towns.

In Norway and Canada considerable progress has been made in the supply to the rural communities, there being no less than 350 out of the 645 rural districts *in toto* in the former country which possess an electrical service.

In parts of Canada great progress has been made in this direction, due mainly to the utilisation of water-power and the consequent large transmission systems which enable rural districts readily to be served by secondary distributing systems.

Though the conditions are very different in this country, it is quite as feasible to afford supplies to rural districts if the people desire to use electricity and will support it locally. The conditions should be better here than in Canada, owing to the greater density of population even in the rural districts.

Apart from work in the field or the application of electricity for intensive culture, the immediate applications which are already being made successfully include the curing of ensilage by electrically served silos, an operation which can be carried out at night; hay-drying; threshing; chaff-cutting; oat-crushing; root-cutting; wood-sawing; milking; cream separation and churning; water-pumping; sheep-shearing; clipping and grooming; incubator heating; besides electrical cooking and heating and the lighting of the farmhouse, byres, and yards. Altogether quite a useful list of mechanical appliances can be compiled through which electricity can help the farmer. In Great Britain the useful pioneer work of Mr. Borlase Matthews is steadily making progress. The problem to be solved is the reduction of the cost of distribution to these generally somewhat isolated farms. Where it can be made commercially possible any increase in the extent of the high-pressure transmission systems constructed in this country must gradually envelop more and more of the rural districts.

On the Continent considerable development has taken place in the provision of an electrical service to rural communities. It is true that

facilities have been afforded in some of these districts by transmission lines conveying the energy derivable from water-power and traversing the rural districts on their way to the main outlet for the consumption of the electricity generated at the distant source. In Denmark, nevertheless, where there is no large water-power at all, a considerable service has been afforded to rural districts, and small pole transformers with cheaply constructed overhead lines are made to serve districts within a two-mile radius from each transformer. Surely we can devise similar means of assisting our great agricultural industry in this country.

This short review would be incomplete without a reference to electrical research—a subject which must always be of interest to this Association.

Excellent progress is being made by the British Electrical and Allied Industries Research Association, now in its sixth year, under the direction of Mr. E. B. Wedmore. This Association was instituted principally by the British Electrical and Allied Manufacturers Association, under the auspices and with the help of the Department of Scientific and Industrial Research. Fundamental researches have been conducted and are being continued on dielectrics in general; on conductors and on apparatus for electric control, including severely practical experimental work on heavy switches; prevention of corrosion in condenser tubes; steam-turbine bladings, and in the properties of extra high-pressure steam up to 1,500 lb. per square inch and at temperatures of 850° F., conducted by Prof. H. L. Callendar. A most important and patiently investigated research into the behaviour of buried cables (that is, cables laid underground in various ways, either direct in the soil or drawn into iron and earthenware pipes) has resulted in obtaining the most useful information of a practical and economic nature.

Great possibilities of a beneficial kind lie ahead of the Association, assisted as it is in many directions by the skilled investigators of the National Physical Laboratory under the directorship of Sir Joseph Petavel. The completion next year of the million-volt testing laboratory at the N.P.L. will make possible tests which will be of great practical value to the industry.

The investigations of the Fuel Research Board begun under the chairmanship of the late Sir George Beilby, now succeeded by Sir Richard Threlfall, and under the direction of Dr. C. H. Lander, will greatly assist the designers of future power houses, as well as generally helping the great gas industry and other fuel industries, including the development of low-temperature carbonisation processes. These researches will have an influence upon public health, will bring about the better utilisation of our fuel resources, and help to educate the general public to a better and less prodigal use of the natural wealth laid down in this old country in past geological times.

It has been a privilege and an education to be associated directly or indirectly with these bodies through the Advisory Council of the Department of Scientific and Industrial Research, and of real assistance in dealing with the problems involved in the consideration of systems for future electrical development.

The work done by these bodies and by the research departments separately established by the great cable-making and manufacturing

firms is bound to be reflected in practical improvements and general progress.

One has got the impression that more encouragement is required to be given to Research Students in Engineering to enable full advantage to be taken of the excellent training facilities offered by our Universities and so that a sufficient number of recruits may be forthcoming.

Development of another kind is rapidly overtaking the *laissez-faire* policy of past years. The Electrical Development Association, under the direction of Mr. J. W. Beauchamp, is making known by educative processes and by practical demonstrations the most efficient manner in which to use electricity for all kinds of purposes. Both classes of development—scientific research on the one hand, commercial application and intelligent use on the other—are bound to benefit greatly the whole industry of electricity supply and the people. The most liberal support and encouragement must be afforded by all electricity-supply authorities.

In 1925 the first World Power Conference was convened in London and was attended by leading engineers and scientists from all parts of the British Empire and the world. A series of valuable papers was submitted on fuel resources, water-power, electrical methods of transmission, and many other cognate subjects. The value of such a gathering cannot be over-estimated, and the success of this first conference was so marked that further conferences are to be arranged and will assemble in other capitals from time to time. The good work thus begun will be continued.

Such is a brief review of the possible future development of the electricity-supply industry in this country. It is clear that a period of great activity and progress is before us, which must inevitably be of great value to the nation.

It is a duty laid on those of us who may be in responsible positions to shape properly and with foresight the lines along which this progress shall be made. Although a steady development is already discernible, much bigger things are before us, and it may be that we shall sow that a succeeding generation may reap. As Great Britain is essentially dependent on imported foodstuffs to a large degree and on other raw materials for the feeding of her essential industries, it is clear that the most efficient and economic systems of industrial power and transport are necessary parts of the future equipment of the country. If we can add to this work of increased power application a notable improvement in the conditions of rural life, we shall help to improve the physical conditions of our people in both urban and rural districts, in addition to providing those engaged in industrial pursuits with better means of competing and holding their own with manufacturers in other countries. In this electricity must necessarily play a great part. Public opinion will increasingly require that this indispensable service shall be brought to the highest degree of efficiency and made as generally available throughout the country as true economic development will allow.

SECTION H.—ANTHROPOLOGY.

THE REGIONAL BALANCE OF RACIAL EVOLUTION.

ADDRESS BY

PROFESSOR H. J. FLEURE, D.Sc.,

PRESIDENT OF THE SECTION.

I. Introduction.

A MEETING of the British Association at Oxford naturally recalls to one's mind the famous stand of Huxley for the Darwinian theory of descent with modification at the 1860 Meeting, as well as his speech at the 1894 Meeting in this city. At the present time there is no longer any doubt among scientific workers that the body and mind of man are the outcome of a long process of descent with modification, and that all life on earth is genetically one. The unity of animate nature is accepted without reserve or qualification, despite little outbursts where old modes of thought linger on the fringes of civilisation. These outbursts serve only to demonstrate the widespread applicability of the principle that survivals tend to have a peripheral distribution.

The general acceptance of the idea makes it important to survey what is known and thought as to how, when, and where the remarkable evolution of modern man worked itself out. Of the early stages of man's evolution little need be said here, as Elliot Smith[1] has recently dealt with it in a fresh and masterly fashion. He has emphasised the correlated improvement of brain and eyes as the key fact. Stereoscopic vision has been promoted by the habit of walking on two legs on the ground, for this freed the hands to carry objects to the mouth, bringing them within range of minute observation by the eyes working together. Improved appreciation of objects was, in his opinion, one factor in the development of names for them.

The period of pre-natal life in apes ancestral to man was probably 220 days, as compared with the period of 280± accepted for mankind. This represents a change of great importance, for it appears to have led to a marked continuance of growth of the head region and to the postponement of the hardening of the frontal and facial elements that must once have occurred soon after birth, *i.e.* soon after the 220th day, but which now is unnecessary at that stage. Increased growth of the fore-brain is a main feature of mankind. We must not, and need not, argue that this increase occurred somehow because it would be useful to its possessors; it is nearer the truth to say that it did occur, and that those who showed it were thereby enabled to take advantage of opportunities their predecessors

[1] Smith, G. Elliot. Lectures on the Evolution of Man, 1924.

could not grasp. That the utilisation of these opportunities led to the survival of the bigger-brained beings is also probably true, but it may well have been a physiological change which started the remarkable process.

The fact that only slight differences in the duration of pre-natal life occur throughout mankind, and that there is a widespread tendency to premature birth about the 220±th day suggests that the extension of the pre-natal period is a very old-established feature of mankind, and is a change from a 220± days' period. It does not seem useful to speculate on the position of extinct early types of man in this respect, apart from a reminder of the fact that they show some measure of increased growth of fore-brain as compared with ape-relatives.

The extension of pre-natal life seems to have induced further important changes which must be mentioned.

First, it seems that the growth of hair is affected. Downy hair spreads over the embryo body, becoming very apparent after about the 100th day, and reaching a maximum about the 200±th day, but afterwards it becomes less and less, though a little remains throughout life, especially in women, and to some extent in men of the Ainu, Australian, and some European groups. It is much less abundant in the negro, though the Bushman retains some of it, and cases of specially marked persistence of the downy hair occur, with other supposed traces of infantilism, among the Central African pigmies. The indications of hair in lines down the chest and abdomen of a woman depicted at Laugerie Basse (la femme au renne) in Aurignacian times should be remembered.

The persistence of an embryonic character such as the downy hair is a remarkable feature in mankind and an example of partial emancipation from the otherwise general rule that development nearly completes itself by the time of sex-maturity. It will be best at this stage of our ignorance to say merely that there is a pronounced prolongation of features of youth in mankind.

From about the 170±th day of life-before-birth the growth forms of hair change, and this change becomes very marked after the 200th day. Now in an ape this is near the period of birth and just after it, and the conditions are necessarily those which promote growth of protective hair. In man, on the other hand, the conditions rather favour maintenance of the downy hair, though it is not so abundant in the new-born as in the 200±th day baby.[2]

Thus the lengthening of pre-natal life seems to have been an important factor in the reduction of hairiness in the human race, and also in the retention of a measure of embryonic downiness, and this has increased the 'tactile' sensitiveness of the skin of those who retain the downy covering, *i.e.* especially of children and women. That this has had consequences for the development of the relations between mother and child is almost beyond doubt.

It is thought by physiologists that the growth of hair absorbs rather a large quantity of energy, and that the thyroid secretion is closely associated with this growth. We shall, therefore, not go far wrong if

[2] Friedenthal, H. Das Wollhaarkleid, Das Dauerhaarkleid, &c., 4 Lieferungen, 1908.

we take it that, with diminished hair-growth, the influence of the thyroid secretion has been liberated to exert itself elsewhere, and, as we understand its relations with brain-growth are also close, we may see in this an accessory factor of brain-growth in man.

The increased brain-growth, whatever its causes, is an outstanding fact of human development, and the corresponding increase of the volume of the skull has apparently made the training for the holding up of the head a longer process, consequently the helplessness of the infant, the opportunities for maternal care, and the delaying of hair-growth are all emphasised. The process of brain-growth and delay of skull-hardening can also be prolonged still further as infancy is lengthened.

The changes just noted have doubtless contributed, from early stages, to the differentiation of men's and women's activities, a differentiation which is a marked feature of our race,[3] for, among other mammals, the two sexes for the most part share much the same habits and run together, though there are well-known partial exceptions. The emphasis on this differentiation of work between the sexes seems to have arisen as man was becoming man in a fairly full sense, and we can hazard an hypothesis as to how it came about.

Man's animal relatives search out nuts and fruits and various forms of vegetable food, and occasionally indulge in animal food; man, even as early as the middle Pleistocene, and probably even earlier still, was partly, perhaps largely, carnivorous. Though General Smuts warns us against overweighting European evidence, we must agree that the Euro-Africo-West-Asiatic quadrant of the world was a very important home of early and mid-Pleistocene man. The cold winter anti-cyclone of that period limited vegetation severely, and, while much of mid-Pleistocene Europe was ice-covered, the belts of climate were shifted southward,[4] so that parts of the Sahara and Arabia got winter rain and were more grassy than now. Lands with climate most suitable to the type of modern man (see details below) would thus be largely grasslands, and here the food problem seems to have urged the men towards hunting, while the women were occupied with maternal duties, probably more necessary under mid-Pleistocene conditions on the grasslands than in earlier times. The success of hunting in providing energising food which helped to maintain body-heat under cold conditions, and generally promoted activity, must soon have become evident, and man became largely a hunter. Women seem to have continued more or less the traditional gathering, but there were no doubt many grades and variations in this differentiation of work. It was not the substitution of a largely carnivorous for a largely vegetarian diet which was so important; rather should we emphasise the supplementary natures of the two diets among people who had not yet the assured position of food-producers. The strenuous exercise of hunting, using the accompanying increase of energising food, would prolong growth and probably retard the oncoming of sex-maturity in the young men.

It is noteworthy that among hunting peoples the difference in stature between the two sexes is still often much greater than it is among cultivating peoples. Here, again, we seem to get another indication of the

[3] Thomson, J. A. 'What is Man?' 1923.
[4] See discussion in *Journ. Roy. Anthr. Inst.*, L, 1920,

prolongation of growth as a feature of mankind alongside of a growing sex-differentiation affecting general habits to a degree previously unknown.

It is, next, very important to remember that this differentiation took place within groups rather than among solitary individuals or even isolated families, for in all likelihood the habit of group-life is part of man's heritage from animal ancestors. So human society does not so much result from the coming together of individuals as human individuality results from the liberation, bit by bit, of individual initiative within groups. This is a fact which sociologists have in the past too often neglected. The different food-quests of the two sexes, the increased dependence of the infant, and the growth of brain all helped to make society more durable and more complex, especially as organised hunting provided a link between the younger fathers and the elder boys. Another factor, which must have operated at the same stage, was Fire. As it was used both by mid-Pleistocene men and by the almost unrelated late Pleistocene men in Europe, it must be very old indeed, and it was almost certainly used by the Foxhall men, who date very far back, while ashes of fires are known from the later phases (Acheulian) of the early Pleistocene. It would help to give society a focus, and to give women another stay-at-home function. Its values for warmth in a cold climate, for food preparation, for scaring wild animals, for hardening and pointing the ends of broken branches, for preparing flints for flaking, are all too well known to need long discussion.

One more theoretical point. Elliot Smith has shown that some measure of human speech is a very old feature indeed in mankind, and the exercise of the faculty of speech is an insistent need all through mankind. Probably progress towards the erect attitude freed the laryngeal region from the constraints of some of the tissues previously helping to hold in place the projecting snout. The increase of family life must have promoted development of intercommunication, and the growth of brain made possible new and varied registrations of associations of sounds with objects, which became better appreciated, thanks to improved detailed vision.

The ceremonial burial at La Chapelle aux Saints in the mid-Pleistocene period is very generally held to imply that, probably from reflection on their dreams, men were already beginning to picture a life after death. This development of fancy can be seen to have bearings on the conduct of nurture, on the relations of the generations, on the continuity and stability of society.

The stone implements of early Pleistocene man are generally of a few types only, though they may be wonderfully executed, with evident affection and æsthetic appreciation. They illustrate the heavy hand of tradition limiting initiative but allowing the compensation of the craftsman's joy, a feature of society one might demonstrate from many regions at many periods.

II.—The Early Forms of Modern Man—General Considerations.

The foregoing inevitably too speculative preface seemed necessary in order to help us to know the rock whence modern man was hewn, and it is the evolution of the forms of modern man that I should like to touch as my main theme. Here we find a difficulty at the outset. Modern man is known first from the north-west quadrant of the Old World, chiefly from

Europe. Research was long hampered by the grouping of all or nearly all the men of the later Pleistocene under the one name of the Cro Magnon Race. Thanks largely to the lamented Giuffrida Ruggeri,[5] we have got beyond that unsatisfactory position, and now recognise several sub-groups of modern man in Europe as early as the Aurignacian period. This implies that modern men had, somewhere or other, gone through a long history before they came to Europe with Aurignacian culture. On the whole the divergences between the various types do not seem great enough, in the present state of our knowledge, to force us to assume that they developed from widely different types of ancient man, but we need not assume a single ancestral pair or even a small number of ancestral pairs all very much alike.

Huntington, Hill, Taylor, and Olbricht[6] have tried in various ways to estimate the climates which make the body and mind of the European function most efficiently, and it is generally agreed that much depends upon the number of calories of heat which the body is able to emit. This amount may be well over 3,200 calories per day for a strong man's active life in a cool climate, and as little as 1,500 calories for a sedentary life under equatorial conditions. More heat can be emitted when the atmosphere is dry as well as cool, as in the United States of America. White people there find it useful to have houses, &c., warmer than ours in England during the winter. The conditions that make us function most actively are those of a climate with temperatures usually varying between 70° and 20° F., without too long spells at either of these limits, with enough, but not too much, bright sunshine, and with variability and storms as a feature. It would appear that these conditions are most favourable to activity and general well-being of some other race types besides Europeans, and Huntington, for example, believes, with some justification, that the Bantu peoples coming into South Africa profit by the greater cooling power of the region, and are physically and mentally better than those in the equatorial regions. Very great cold appears to have deleterious effects mentally and physically. We must not argue too crudely that the 'ideal climate' is the climate of the region where modern man originated, but we may go so far as to say that, as his constitution seems attuned to certain climatic conditions, those conditions must not be very far from the conditions of the region in which he evolved, admitting that quite possibly he migrated into a region of the climate in question and so gained an access of vigour. His mental processes are most active at a temperature below that of the greatest comfort physically, and this has induced Olbricht to venture the suggestion that the great mental advance to the fully human condition occurred in a cold period, probably one of the later phases of the Ice Age.

[5] Giuffrida Ruggeri, V. 'Quatro crani preistorici dell' Italia,' *Arch. per l'Antr. e la Etn.*, xlv., 1915; 'Antropologia e Archeologia,' *ibid.*, xlvi., 1916; 'La posizione antr. d. Uomo d. Combe Capelle,' *Riv. di Antr.*, xxi., 1916-17; 'Su l'origine dell' Uomo,' 1921.

[6] Huntington, E., 'Civilisation and Climate,' 1915; 'World Power and Evolution,' 1919. Hill, L., 'The science of ventilation and open-air treatment' (Medical Research Committee), pt. 1, 1919, pt. 2, 1920. Hill, L., and Campbell, G., 'Health and Environment,' 1925. Taylor, G., 'Evolution and Distribution of Race, Culture and Language,' *Geographical Review*, 1921. Olbricht, K., 'Klima und Entwicklung,' 1923. Cornish, Vaughan, 'The Great Capitals,' 1923.

If modern men are descendants of one ancestral group, it was probably a group of Pleistocene and possibly of mid-Pleistocene date. At that period, we may take it that the requisite climatic conditions obtained in various parts of the belt now forming the Sahara and S.W. Asia, for the belts of climate then lay farther south, and the winter westerlies apparently visited that belt; it is interesting that the Sahara shows a good deal of evidence of inhabitants of possibly mid-Pleistocene date. We may, perhaps, venture to 'place' the ancestors of modern man in the zone from the Atlantic edge of the Sahara to Persia, and may think of several groups not all exactly alike. Those on the colder side of the zone may well have been distinguished by greater mental activity.

What were the early modern men like? Firstly, as all men of modern type walk nearly erect and as the older extinct types of man did not, we may argue that an advance, still incomplete in some cases [Grimaldi (lower levels) and Chancelade], towards the erect posture was characteristic of early modern man. Next, nearly all healthy men show some tendency to produce brown pigment, and, save in N.W. Europe, have dark hair and eyes. In fact, these are almost universal in the rest of the world except for migrants from North Europe, in which area (possibly also, slightly, in parts of N.E. Asia) therefore a process of depigmentation has most probably occurred. So it is likely that early modern men were more or less brown-skinned, dark-haired and dark-eyed, and if this be so they doubtless lived where there was a good deal of summer sunshine, as, no doubt, there was in the region indicated.

Next we note that, however strong the jaws and brow-ridges of modern types of men (fossil or living) may be, they are less strong and project far less than those of the most ancient types of men. Reduction of jaws and brow-ridges is thus a process we can postulate, and we may go one step farther and associate this with progress towards the erect posture. Reduction of face and jaws would certainly make it easier to balance the head on the end of the vertebral column, and this reduction was undoubtedly made possible by increased use of the hands. There was also, no doubt, some influence of what Roux called the 'Struggle of the Parts,' according to which parts that are of increasing importance draw nutrition during development from their neighbours. In this case it would be the growing fore-brain that was capturing energy. It may also be that there has been a relative reduction of the pituitary secretions or of one or other of them, and it has already been suggested that there had been a liberation of thyroid secretion from old duties, or even an increase of that secretion.

III.—Early Forms of Modern Man—A Brief Summary.

Among the early (Aurignacian and Solutrean) examples of modern men we notice a good deal of difference of characters, and this suggests a number of ancestors spread over a fairly large zone rather than an origin from a very small group of very localised origin. It is admitted that the number of skeletons known is, as yet, too small for us to argue with confidence about races and migrations in that early time. Nevertheless, it is useful to have some working hypothesis, and for this purpose we shall

venture to sketch out characters of some groups of men of the periods in question.

The well-known youth and old woman from the lower layers at Grimaldi[7] show very long high heads, which, however, altogether lack the brow-ridges found in some of the others. The nose is very broad and the mouth projects strongly, while the teeth are much larger than those of living men. The stature is short.

These two skeletons have been said to be 'negroid,' but it would be better to say that, both in them and in some African individuals, we find some of the characters above enumerated. If it is right to look upon a marked relative elongation of the head as an early specialisation in some, but not all, forms of modern man, then we can say that these two Grimaldi skeletons show that specialisation, and are also characterised by absence of brow-ridges. The proportion of the lower limb to the upper one was remarkably high, as Verneau has shown, and it is interesting that this seems also to be a feature among some African peoples, notably the Bushmen. The relations are quite reversed among some West African negroes, and apparently among the Semang pigmies. There thus seems reason to suppose that among the early forms of modern man—for I shall claim later on that the pigmies are, to some extent, survivals of such forms—there were differences in the proportions of the limbs. This is what might be expected to occur in a species with an original home probably on the grassland borders of the forest, and possibly an arboreal stage in its ancestry.

Menghin[8] has recently ventured the suggestion that the Grimaldi type is to be linked with the rock-face art of Alpera and other places in E. and S. Spain. The idea is that here we have a type and culture related to those of N. Africa, though the indications are that the culture (Capsian) concerned reached Europe from Africa *via* Italy rather than *via* Spain.

The name of Cro Magnon has been widely used as a label for nearly all the types of the late Palæolithic with the exception of the two Grimaldi skeletons above mentioned, though often the calotte from Brünn or that from Brüx, both in Moravia, have also been made into types. The late Giuffrida Ruggeri helped greatly to make our conceptions clearer, but some exaggerations of Klaatsch hindered the spread of a more reasonable view. It is interesting that Klaatsch withdrew those exaggerations before he died.

Three individuals are known from Cro Magnon,[9] one, 'the old man,' being almost perfectly preserved. There is also a very closely similar skeleton from La Grotte des Enfants on the Riviera. Further, two male skeletons from Barma Grande (Riviera), and possibly two or three more from Cavillon and Baousso da Torre (Riviera), show facial characters of this type combined with the very long and high-ridged character of the skull-roof of the type to be discussed next.

This combination of the broad, short, strong-jawed Cro Magnon face, with a very long and high head as just noted, also occurs in the male skeleton of Magdalenian date from Obercassel, near Bonn.

[7] Verneau, R. 'Les grottes de Grimaldi,' vol. ii., 1906.

[8] Hoernes-Menghin. 'Urgeschichte der bildenden Kunst in Europa,' 1925.

[9] de Quatrefages, H., and Hamy, E. T., 'Crania Ethnica,' 1882. Also Verneau, R., *op. cit.*

In the Cro Magnon type the head is long absolutely, but only moderately long relatively, so the cephalic index is moderate (74-5-6). The malar bones are strong, and it is clear that both the temporal muscles and the muscles for lateral working of the jaws were powerful. The height of the skull is much less than its breadth. The nose and chin are prominent and narrow. The stature is great. It would seem that the pull of the jaw muscles was exerted well away from the median line, and with this standing out of the jaw muscles at the side seems to be associated the breadth of cheek-bones, orbits and jaws, which is such a marked feature here. The pre-frontal region seems to have grown out to the level of the heavy brows, so that the latter do not project out as strong brow-ridges, though the eyes are deep-set beneath.

It is difficult to accept either the Brünn or the Brüx [10] skull-caps as suitable subjects from which to name a race, and there are difficulties about naming it from the allied skull from Combe Capelle. Science is waiting anxiously for a full account of skulls found at Predmost, as it seems likely that these will furnish a useful basis for naming the type. The general characters here are the extreme length and narrowness of the head, so that the cranial index is rarely as high as 73 on the skull, and the strong development of the brow-ridges. It was once supposed that the strong brow-ridges betokened Neanderthaloid kinship, but that idea has been given up, though some have discussed whether the skull-cap recently found at Podkoumok [11] in the Caucasus should not be included in this group rather than in the Neanderthal group. The accepted distinctions between the two groups have included the lowness of the vault in the Neanderthal group, and the fusion in that group of all the elements of the brow-ridges and glabella to form a frontal torus.

It has, however, been found that some of the Lautsch skulls (Moravia) are very low in the vault, and this is true for one from Mechta-el-Arbi (cranial index, however, 76.7) in N. Africa. In one of the Lautsch skulls also the brow-ridges and glabella are fused, though there is nothing like the strength of the frontal torus of the Neanderthal type. It may be that the progress of discovery will lead us to a knowledge of a type approximately ancestral to both the Neanderthal group and the group now under discussion, these two representing divergent specialisations.

From the fact that Brünn, Brüx, Lautsch, Predmost are all in Moravia one may speak tentatively of the Moravian group, with the Combe Capelle skeleton as an outlying find in the French Aurignacian. The group is important because it is so widely represented in skulls of subsequent periods and in present-day populations, in both cases with modifications in detail.

The Combe Capelle, Brünn, and apparently some Predmost skulls are high, with the median line standing out as a ridge. Where it is known, the face is longer and less broad than that of the Cro Magnon type, though here again the cheek-bones stand out. The nose is sometimes fairly broad, the stature is moderate.

Menghin has ventured the suggestion that this type may be linked with

[10] Schwalbe, G. 'Die Schädel von Brüx,' *Z. für Morph. und Anth.*, 1906.

[11] Fleming, R. M., 'The Podkoumok Skull,' *Man*, June 1926. Szombathy, J., 'Die Menschenrassen im oberen Paläolithikum,' *Mitt. Anth. Ges. Wien*, 1926.

the art of sculpturing in the round, so characteristic of some Aurignacian stations in Europe.

Skulls from Solutré show high heads apparently without strong brow-ridges, but here the head is relatively shorter and the cranial index is much higher (77.9-83.2, as against 74-5-6 in Cro Magnon, and about 70 or less in several others). We await with great interest further details of these Solutré skulls.[12]

IV.—A Comparative Review of the Early Forms Noticed.

We must note first that it is no longer possible to speak of the people of the Aurignacian and Solutrean phases as all long-headed ; the Solutré skulls show that fairly broad-headed men had already appeared in Europe at that time. It is also evident that there are several characters which are widespread among these early forms of modern man, but that these characters occur in different associations in different cases. Extreme long-headedness is common to several specimens, and is usually, but not always, associated with high-headedness and with strength of brow-ridges and of cheek-bones, connected with great strength of the temporal muscles. There is, however, also a fairly frequent occurrence of a somewhat greater width combined with less height of head, as in the Cro Magnon type, and here it would seem that the brow-ridges do not stand out forwards in most cases. The temporal muscles were undoubtedly strong in this last type, but they seem to have been set farther out to the side.

The increase in length of the skull, which undoubtedly seems to have occurred in the early forms of modern man, appears to have been mainly an increase in length in front of the ear, and it is important that, in children's growth, the part of the head in front of the ear increases in length more and faster than the part behind the ear. Here it is interesting to note that the Chancelade skull seems to have less lengthening of the front part than many others, and to remember also that Chancelade man did not walk quite erect. He has not been described in the previous section because he is later in presumed date than those mentioned, but he appears to show some early features.

Now, if growth was taking place particularly in the anterior region of the skull, and was often especially growth in length, this means that additions were being made most of all along the coronal suture which goes across the head near the vertex, and we may inquire why this was so. One reason seems to be that the temporal muscles, functioning strongly when the jaws were used for tugging at flesh food, were obviously of very great importance to the men of the late Palæolithic Age, as they had been to earlier man and to his animal ancestors. In other words, a persistent ancient feature frequently exercised a marked influence on a new growth. In several cases the two sides of the skull-roof were pulled down, or the median line was ridged up, and this is found frequently associated with a deep temporal hollow, and markedly outstanding brow-ridges remain as a natural consequence. These are not new features but, rather, persistent old ones. In other cases the front part of the roof is less gabled,

12 Depéret, Arcelin, and Mayet. 'Découvertes d'hommes fossiles d'âge aurignacien et le gisement préhistorique de Solutré,' *La Nature*, 2587 (1923) and 2654 (1925).

and the brows are then usually less outstanding as elements distinct from the brain-case. In other cases again the temporal muscles seem to exercise still less influence on the skull, and growth is not so predominantly a growth along the coronal suture; here the head is less narrow, the brow-ridges are generally weaker, and, especially in women who have little growth of brow-ridges, the forehead may even bulge forward to some extent above the brows.

Lest too much importance be attached to the influence of the temporal muscles upon the skull-form attained as growth proceeded, it is well to remember that the face was still strongly developed in most early examples of modern man, and that to balance this the head must project backwards a good deal; therefore growth in length would be marked in those forms which had a weighty development forwards. This occurred in most cases, whether the skull was very narrow and high or less narrow and lower. This growth in length leading to backward projection resulted, as has been said, chiefly from growth of the front part.

In trying to understand the variations in form of early Neanthropic men's skulls as essentially growth-differences, it is well to remember that the man of Neanderthal type from La Chapelle aux Saints had a cranial index in the neighbourhood of 80 if the brow-ridges be excluded in taking the length. The relation of breadth to length in the Piltdown skull was about 79 per cent., and most of the apes are brachycephalic (apart from the brow-ridges), though H. A. Harris has recently shown that some gorillas are dolichocephalic.*

It is thus possible to think that, with the growth changes involved when there evolved men of the types found in Aurignacian and Solutrean times in Europe, some individuals responded with little change of cranial index and became what are often called mesaticephals or sub-brachycephals. Others responded with a lesser or greater degree of growth in relative length, not in absolute length be it noted. The skulls with very low cranial index and great height so characteristic for the Solutrean, and to some extent for the Aurignacian phase of culture, are thus held to be an early specialisation among men of modern type, and this view is contra-distinguished from that which has been suggested from time to time, and which supposes that dolichocephaly was the one primitive condition in men of modern type, and that brachycephaly somehow evolved from it.

When the types of living men are studied, it becomes evident that the heads which have a very low index have a distribution which includes the following features:—

(*a*) Many of their locations are peripheral, as though they had been pushed out to the very edges.

(*b*) Some of their peripheral locations, and many of those which are not peripheral, are in regions of difficulty which are typically refuges of old types.

It is unreservedly recognised that this does not account for all the facts. There are, for example, types—*e.g.* in S.E. Australia—with low indices and heavy brow-ridges, but the head there is generally low, not high, as would be anticipated from what has been urged here. I think

* 'Endocranial Form of Gorilla Skulls,' *Amer. Journ. Phys. Anthr.*, 1926, p. 157.

this point could be met by more minute speculation as to evolution of types; they may be a very early variant. It is also proper to add that in N.W. India there are large numbers of men with very high heads of very low index, and that area is neither peripheral nor a region of difficulty. This problem needs to be thought out in its prehistoric setting, but I do not think it, as yet, invalidates the view here sketched out.

It is still far too early to build on the suggestion, but one may use as a preliminary sketch the idea of the evolution of very long-headed early modern men somewhere on the great plains from Cap Verde to Persia, and of their spread to the great plains north of the Euxine, as well as to S.W. Europe. If, at the same time, one thinks of types with less lengthened heads, for example in the highlands of Asia Minor and on the southern flank of the Cap Verde-Persia area, one has a picture which will be of use till a better can be made. That the early home of modern man was a broad zone, with local differences in types of people, can hardly be doubted.

Before proceeding to a rapid survey of some living groups of mankind we must note a few more features of early modern man, features in which he seems to contrast with his predecessors.

Ceremonial burials became frequent, and in a few cases group-burials also indicate increased group-life, and artistic expression found special development in the carving of statuettes, emphasising especially the fact of maternity. There is also clear indication of liberation of initiative within the group, in that implements took on more varied forms for various purposes and in various localities; and, in handling quantities of them, one cannot but feel that men were more accustomed than heretofore to throwing away an old implement and taking a new one. There can be little doubt that with the growth of social life went an increase of parental interests, with the probable accompaniment of prolongation of infancy, and, very probably with this, of prolongation of the whole life cycle. Increased possibilities of education would seem to have been opened up, and would in their turn not only help to lengthen the adolescent phase, but could also contribute to the refinement of the hand and the completion of acquisition of the erect posture.

V.—Some Possible Survivors of Early Types of Modern Man—the Pigmies and Others.

Had we the whole pageant of evolution before us we should expect to find that early stages of the evolutionary changes noticed above survived here and there, especially in out-of-the-way places or unfavourable situations. We should expect to notice amongst them degenerative as well as primitive features, and probably evidences of infantilism. Near the base of the vertebrate genealogical tree cluster such forms as Amphioxus, Appendicularia, Tunicates, &c., each with a medley of primitive, degenerative, and infantile features. Similarly near the base of the Molluscan genealogical tree occur Chætoderma, Neomenia, and Chiton.

Looking at certain groups of living men with these analogies in mind, and thinking of their present distribution in relation to the supposed home of the earliest men of modern type, we are led to interpret some

characters as survivals of early stages of the evolution of modern man from ancient man. These characters may be accompanied by indications of infantilism and perhaps of special adaptations.

The Andamanese, Semang, Aeta and Tapiro all live around the south-easterly fringe of Asia, in a region where land-connections must have been far more extensive when the coastline was near the present 100-fathom line. They are all very short, with small heads of moderate relative length, *i.e.* there is every ground for thinking that among them the growth in length noted for a number of early types of modern man has not taken place. Their noses are flat and broad, again an early feature, but this is less marked in the Tapiro. The skin is very dark and the hair is set in close spirals. It seems almost necessary to think that some of these types have left their mark on the population of various parts of India. Papua has other pigmy and short peoples besides the Tapiro, people who have spirally curved hair and are moderate-headed, some even very long-headed. In the Semang the ratio arm/leg is said to be unusually high.

The Akka and other pigmies of equatorial Africa are again small and small-headed, the relative head-length being again only moderate, so that the cephalic index is 77-81, but lower in some groups. In these people pigmentation is less than it usually is in Africa, and downy hair occurs in notable development, especially on the legs ; these points suggest partial infantilism, especially as the very short stature is due rather to extremely short legs than to smallness of the trunk-length. The absence of the very dark colouring otherwise so general in Africa has been supposed to be due to forest life, and this environmental influence may have played an important part in the evolution of the pigmy.

The Bushmen of S.W. Africa are a little taller than the above; their body is poor in hair, though the hairs are in close spirals, and among them Fritsch[13] finds down-hairs (lanugo) here and there. The head, according to Broom,[14] has small measurements, but the relative length is greater than the above, so the cephalic index on the skull ranges down from 78 to about 72 ; the head is low in the crown. Are these survivors of a stage in the lengthening process, or are they due to a cross between two types ? It has sometimes been supposed that the low stature of the Bushmen is a result of poor feeding. The skin-colouring is not very dark. The nose is very broad and flat, the brow-ridges are not marked, but the cheek-bones stand out.

The Tasmanians, now just extinct, were of moderate height. The head form ranged from brachycephaly to well-marked dolichocephaly. One skull, for example, is 205 mm. in length and has a cranial index of 72.2. The basi-bregmatic height of the skull is not great, but its average value is only 5 mm. less than that of the breadth, and only 75 per cent. of the skulls known from Tasmania have the height less than the breadth. The colour of the Tasmanians was very dark, their hair was in close spirals and was fairly abundant, their nose was very broad and flat. Their brow-ridges, in contradistinction to those of the peoples mentioned

[13] Fritsch, G. 'Das Haupthaar,' 1912 ; 'Die menschliche Haupthaaranlage,' 1915.

[14] Broom, R. 'Craniology of Yellow-skinned Races of South Africa,' *Journ. Roy. Anthr. Inst.*, liii., 1923.

before, are strongly marked. On the whole the Tasmanians seem to have descended from early types of modern man in whom the process of skull-lengthening, inferred above, had proceeded some distance.

VI.—Some African Features.

Before going any farther, attention must be drawn to the curious problem of the hair, which in all these types is in close spiral curves. Now, ape-hair is wavy, with roots stretching down into the deeper layers of the skin, and Sarasin[15] and Junod have recently claimed that it is only at about the time of birth that the hair of a negro child becomes spirally curved. Fritsch has shown that the slighter, or downy, hairs of the Bushman have a fairly straight course up from the roots, and that the spirally curved hairs develop that curve just above the root, often with a fairly sharp angle between the root and the beginning of the curve. For the moment it seems probable that these slighter hairs are part of the downy-hair covering already mentioned, but it would not be safe to assume that they are the modified survivors of ape-hair; they may be. In any case it would seem that among some early representatives of modern man, if not earlier still, a specialisation of hair-growth occurred and produced the 'spiral' types of hair among those groups which were on the south side of the presumed early home of modern man. That specialisation has fixed itself racially, in the end, at an early stage of growth. Factors of equatorial climate probably contributed to this result, for by this change the hairs were concentrated nearer the surface and the blood could thus be brought near the surface, and possibilities of cooling could be increased. This condition is a step towards that which obtains in various degrees among African peoples, in which the blood-vessels of the skin are abundantly developed. It is worth noting that the Aurignacian statuette called the 'Venus of Willendorf' is sculptured to suggest woolly head-hair, while the 'Sorcerer' of Lourdes is drawn to show wavy hair.

Next, we may think of the cases in which the lengthening of the head argued in an early paragraph has taken place fairly clearly and completely; but for the moment we shall consider only those of the southern lands of the Old World, those who may have drifted southwards from the early home of modern man. Certain Hottentots and Koranas measured by Broom[16] are distinctly taller than the peoples discussed above, their heads are often quite long, absolutely as well as relatively, and their cranial indices range from 64.2 to 72.3 on the skull. The brow-ridges are often very strong, and some men have more face-hair than is usual in Africa; the hair is spirally curved, as usual. Some are tall and strongly built. The height of the skull is usually as great as, or greater than, the width, so in this feature again they illustrate what I have supposed occurred in some types of early modern man. The ancient S. African Boskop[17] skull differs from these in some ways, just as the Cro Magnon

[15] Sarasin, F. 'Sur le changement de la chevelure chez les enfants des Mélanésiens, et des nègres Africains,' *L'Anthropologie*, 1925.

[16] Broom, *op. cit.*

[17] Pycraft, W. P. 'On the Calvaria found at Boskop,' *Journ. Roy. Anthr. Inst.*, 1923.

skull differs from those of Predmost and Combe Capelle; its height is much less than its breadth.

Thus it is seen that from Africa (south of the Sahara) we can match, *mutatis mutandis*, the known early Aurignacian types of Europe, allowing that the best matching of the Grimaldi type on the whole would be with some of the true negroid types to be mentioned next. Among the negroids we find a general indication of long-headedness as a basic character; high-headedness is also widespread, and both features are sometimes developed to extremes. The close-spiral hair arising from curved roots near the surface of the skin, the great development of blood-vessels in the skin, the poverty of body-hair and the utilisation of the sebaceous secretion for keeping the skin surface supple and alive, so that non-conducting layers do not accumulate much, the variable but dark colouring, the flat broad nose (in many but not all cases), the thick everted lips are all well-known characters. Some are presumed here to be inheritances from early types of modern man, retained in some cases because infantilism seems to be apt to occur; in others, such as that of the broad flat nose, because the features are of value to promote cooling. Others may be specialisations, including perhaps the close-spiral hair, the great development of skin blood-vessels, the everted lips, the thin supple epidermis without many dry dead layers, all of which would promote cooling. The Bushman [18] in the desert has a fair thickness of dry skin, and has not the great development of skin blood-vessels seen in some other African types.

It is interesting to note the general dark colouring of the presumed survivors of early man in the southerly lands of the Old World, with the exception of the African forest pigmies and the Bushmen. It may be that the pigment formerly supplying the hairs remained in the skin as the hair diminished in quantity, especially in view of the fact that a certain amount of pigment is a valuable protection against the too great influence of the shorter visible (blue end of spectrum) rays of the sun.[19] The ultra-violet rays are mostly filtered out by the horny layers of the epidermis. One should remember that deposited pigment is probably also waste matter laid aside where it can do but little harm, and that pigment of the surface above blood-vessels is a widespread feature in Vertebrates, Arthropods, Molluscs, &c. It was obviously especially types with broad flat noses, prominent mouths, and feeble brow-ridges and spirally curved hair that spread southwards in Africa, but a brow-ridged type also went that same way.

VII.—South-eastward Drifts of Early Types of Modern Man, as Represented in Present-day Populations.

The supposed southward drift into Africa south of the Sahara was a drift affecting chiefly the people of the southerly belt of the zone early modern man is held to have occupied. What may be called the south-easterly drift would be a drift of somewhat different character, a drift from the eastern end of the zone and a drift thus affecting not only the people of the southerly belt but also those of the belt farther north. Thus

[18] Fritsch, G., *op. cit.*

[19] Hill, L. 'The Science of Ventilation' (*vide supra*), pt. 1, pp. 122-3, 1919.

there drifted in this direction not only the little peoples with small non-lengthened heads, who reached various points around S.E. Asia, as already mentioned, but also other types. The Tasmanians, for example, also showing spirally curved hair, have heads to some extent lengthened, and the brows are well marked. The Australian natives, with their very long heads and strong brow-ridges, broad flat noses and prominent mouths, are in some ways comparable with the Koranas of S. Africa,[20] but have wavy hair growing from fairly straight roots. The height of the head is often small in S.E. Australia, but is great in N. Australia. Their resemblance to the Vedda of Ceylon is universally recognised.

In Papua and Melanesia, on the other hand, though many of the same skull- and face-characters are present, the hair is in spirals. Nevertheless, it is to be noted that, whereas the African hair is said by Sarasin and Junod to change in character about the time of birth, they claim that the change in Papua and Melanesia comes when the child is from two to four or five years old. In Melanesia it would appear that there is, as one would expect, much admixture.

As has been indicated, then, the south-easterly drift of the older varieties of modern man seems to be a more varied one than that into inter-tropical Africa, and this is apparently due to the fact that it is a drift from the eastern end of all belts of the zone of occupation of early modern man as well as to complexities of physical geography. One cannot but suppose that the earliest drift in this direction was of people with dark skins, spirally curved hair and non-lengthened heads, but that there followed people with more lengthened heads (Tasmanians in one direction and Melanesians in another, though the two groups are not at all closely related). Subsequently there would seem to have followed people with the fully lengthened head, but with wavy hair, people, however, retaining dark skin. These early drifts have obviously intertwined, as one would expect from the relative narrowness and the great length of the belt through which they moved.

To understand these drifts a little more closely one may move the coastline of S.E. Asia to about the present 100-fathom line, thus adding Ceylon to India, as well as Sumatra, Java, Bali and Borneo to the Malay Peninsula and Cambodia. Palawan would then become a peninsula stretching north-eastwards from Borneo, and almost making contact with the Philippines, which again would almost attain contact with N.E. Borneo on the other side of the Sulu Sea. Farther east, Papua would be united to N. Australia, and only narrow straits between N. Australia and Timor, between Timor and an enlarged Lombok-Flores-Ombaya, and between this enlarged island and Bali, would separate the land masses of this region.

VIII.—North-westward and North-eastward Drifts of Early Types of Modern Man, as Indicated in Present-day Populations.

Hyperdolichocephalic people occur here and there in the European quadrant of the Old World, in Ireland, Wales, Norway, the Dordogne, Tras-os-Montes in N. Portugal, in Sardinia, in the south-east Carpathian region, and in N. Africa. The appropriate type of skull is a noteworthy

[20] Broom, *op. cit.*

feature in Kurgan burials in S. Russia. Sometimes, as in N. Africa and in Wales and France, at least, the people concerned suggest likeness to the Grimaldi type. In other cases the resemblance is rather to the Moravian group or the Combe Capelle skull.

Rodd[21] has claimed that the Libyans include people who show the features of the Cro Magnon type. Telesforo de Aranzadi[22] makes similar claims for Biscayan Spain, and Collignon made them also for the Dordogne.[23] The survival of the Cro Magnon type is perhaps hardly established, but it seems probable.

We may thus form the idea that a basic element in the population of the European quadrant is a very old mixture of early types of modern man, with subsequent inter-breeding and modifications. In addition to this basic element there are immigrants of other types from outside.

When the ice sheets were retreating finally the way northward between the Elburz Mountains and the Hindu Kush was probably beginning to be opened up, though doubtless the ice sheets on the Pamirs and adjacent ranges were still mighty, and the highland plateau of Mongolia, and much more the mountains of Thibet, were certainly still almost uninhabitable. Doubtless, therefore, men spreading in this direction were from the first possessed of characteristics protecting them from bitter cold.

Men with very long, high heads who appear to be linked at least distantly with the early types mentioned in a previous section have reached America by north-eastward drift, at first avoiding the great highland mass of Central Asia.

Some living near or on the ice sheet would seem in the end, probably long after this period, to have reached the Arctic tundra, and to have suited their mode of life to its environment. It is as survivors of such people that I interpret the Greenland and Baffin's Land Eskimo, without in any way suggesting that they go back to high antiquity in these particular regions. Others reached the American pine forest, and long-headed, high-headed types are known from skulls in the eastern States of North America. Others are scattered here and there in North America, in the extremity of the peninsula of Lower California, for example, also in a few spots in Mexico. In South America[24] there are both skulls of some antiquity and living people with these head characters on the plateau of Central and East Brazil, and old skulls in Colombia as well, while analogous features existed among some peoples of the extreme south. Hrdlička has advanced arguments for racial resemblances throughout the ancient native population of America, and we would look upon these extreme long-heads as the first and most peripheral wave of a series generally becoming broader-headed with each succeeding wave.

The Ainu of N. Japan and Sakhalin and some ancient crania from Japan seem another wave of early types surviving in what is in a sense

21 Rodd, F. 'The Origin of the Tuareg,' *Geogr. Journ.*, 1926.

22 de Aranzadi, in a letter to Dr. Haddon, 1918.

23 *Mem. Soc. Anthr. Paris*, t. 1, No. 3, 1894 (Dordogne).

24 Rivet, P., 'La Race de Lagoa Santa,' *Bull. Mem. Soc. Anthr.*, 1909. Hrdlička, A., 'Early Man in South America,' *Amer. Bureau Ethnol.*, lii., 1912; 'Origin and Antiquity of the American Indian,' 1925. Verneau, R., 'Crânes d'Indiens de la Colombie,' *L'Anthr.*, xxxiv., 1924.

an ultimate corner, but among them apparently the specially long-heads are not in the majority. None the less, long-headedness with high-headedness is a feature here. The Ainu also stand out in contrast to most other peoples of East and North Asia in having very hairy bodies. Extreme hairiness may be looked upon as a protective scheme alternative to the development of the very dry skin with very few hairs, characteristic of Mongolia, &c.

Looking generally at the early spread of man northward in Asia, we note that yellow-brown or brown or red-brown skin is a widespread feature. It is partly a maintenance of early pigmentation, partly, perhaps, an adaptation of that pigment to conditions of snow-glare and sunlight in a cold climate along lines which are being made the subject of physical investigation. The skins are usually well provided with dry epidermal layers, as would be natural in such climates. For the most part, hair-reduction has been carried to an extreme, and such hair as remains grows in firm pores in such a way as to fill the pore very completely. Sweat-glands also are not over-numerous, and, in consequence of this, skin garments can be worn without undue discomfort for a long time. A skin of this kind has a low irritability, an important fact in relation to the equability of temperament and relatively low sensibility to pain that is characteristic of many of the peoples who have spread north-eastwards in Asia ; needless to say, modifying factors affecting the temperament in other ways could be discussed. A moderate nose and strong cheek-bones may be supposed to be a general ancient feature of these peoples, but this matter will be discussed later. The diet generally includes a good deal of fat, thus encouraging production of heat that balances the high cooling power of the environment. Some of the broader-headed spreads in the directions indicated have reached regions with warmer seasons, and have adopted very different diets, especially as the type of skin just discussed does not make easy the dispersion of internal heat.

Some broad-heads spreading northwards in Asia took the river-bank ways, such as that of the Yenisei, and, arriving on the tundra, ultimately found the westward route *via* North Russia to Scandinavia possible as the ice sheet of the latter diminished. This last spread must have been relatively late.

In concluding this brief review of early spreads of man and of their probable effects on present-day populations, it is well to refer to the interesting new light that is beginning to be shed on racial problems by the study of blood groups.[25] The results are fragmentary and still lack correlations, but it already seems that, in some extreme peripheral regions, such as Australia, America, Iceland, and, to some extent, N.W. Europe, the proportions of persons with Groups III or IV of the usual blood-classification scheme are very low indeed. It is as though a large element of the blood of these peripheral peoples was inherited with little alteration from a phase before certain specialisations occurred in the composition of the blood.

[25] Snyder, L. H. 'Human Blood Groups,' *Am. Journ. Phys. Anthr.*, 1926.

IX.—Post-glacial Changes and Food Production.

According to de Geer, sinking of land in North-West Europe contributed to rapid retreat of ice sheets about 6000 B.C., and the belt of the Atlantic westerlies shifted northward to its present position. The Central Asiatic ice sheets would thus be diminished through reduction of precipitation in consequence of this shift. For some millenia the Central Asiatic ice continued to yield enough water to keep moist certain areas that are now arid. Farther south the Mediterranean region and especially Mesopotamia were acquiring their well-known alternation of a cool rainy with a dry warm season. Mesopotamia doubtless long retained a good deal of moisture from melting of mountain-ice, especially as there was occasional slight regrowth of ice, as in the 'Gschnitz' period of the glaciologists. This, however, was followed by marked subsidence of land in N.W. Europe, giving the mild conditions of the 'Littorina Sea' in the Baltic area, and presumably considerable heat farther south (*e.g.* in Mesopotamia).

The change of climate in N.W. Europe brought pine forest to replace the earlier steppe, and this was a serious crisis for the animal and human inhabitants. A pine forest is generally unfriendly to men who depend on collecting for their own needs, and the old culture seems to have decayed, leaving fragmented groups near the shores living on shell-fish, &c. Some patches free of forest because of loess soil or porous rock seem to have retained a hunting population, but the general condition seems to have been one of poverty and stagnation, though Kossinna thinks the south Baltic shores saw an advance of culture which most other students ascribe to awakening influences from the south-east at a later date. The oak forest succeeded the pine, and might have brought better opportunities had there been indigenous food-plants in W. or N.W. Europe. As it was, however, what may be called epipalæolithic conditions continued for long ages in the west.

The probable early home of grain was in some part of the Fertile Crescent around the north end of the Arabian Desert, and food production was already undertaken there, *e.g.* at Susa, about or before 5000 B.C. A culture complex, which included cultivation of wheat and barley, the art of stone-grinding, that gave rise to the wedge and a mastery over work in wood, the hafting of tools, pottery, the beginnings of domestication of animals (possibly mainly for milk), the dawn of metallurgy and other arts, seems to have arisen in the Fertile Crescent; and the Nile area may have contributed to, as well as been helped by, this. Evidence is as yet fragmentary, but there are indications of the spread of elements of this culture complex during the fourth millennium B.C. to W. Europe, probably *via* Hungary.[26] The lake-dwellings of Switzerland seem to be a result of this. A spread of early Danubian culture to Belgium is held by several to have brought agriculture to W. Europe. There is, however, no need to picture the awakening West as copying exactly from old and distant civilisations. One will be nearer the truth if one thinks of the incoming of a germinating influence. The mastery of a wood technique, food

[26] See further discussion in 'The Corridors of Time,' H. J. E. Peake and H. J. Fleure (in the press); also Childe, V. G., 'Dawn of European Civilisation,' 1925; Hoernes-Menghin, *op. cit.*

production, and the art of the pottery all contributed to home-making, to the provision of soft food for infants and to the enhancement of parental opportunities. Thus began the development of our agricultural civilisation of W. and N.W. Europe with its more and more settled life and its improving equipment. It is in relation to these changes that one may picture the continuation of a progressive diminution of the jaws and the brow-ridges, but one must remember the long persistence of ancient characters in the north-west, where they are found frequently enough among the skeletons from graves of the period of transition from stone to metal. Menghin is inclined to think that there was a direct inheritance from the old loess hunters of Hungary and Moravia to the later agricultural peasantry of that region.

X.—Brachycephalic Types.

We have seen that the Palæolithic flesh-hunters without pots or pans must often have pulled at flesh-food half raw with their jaws, and their temporal muscles had to remain strong and firm, giving a head growth towards the long and high form. But among the mountains and forested valleys there may well have remained people among whom the lengthening of the skull may have been less marked (*cf.* Sect. IV), peoples for whom roots and seeds and berries were more important, and who, as Prof. Thomson and Mr. Buxton would put it, used their chewing (masseter) muscles far more.

Among such people the general human tendency to reduction of brow-ridges would find freer scope, and the general head-growth could express itself more freely by increase of both diameters. I am thus inclined to venture the hypothesis that broad-headedness is not so much an evolution from long-headedness as a separate evolution from a medium-broad condition of very early modern man as already suggested (Sect. IV). A further hypothesis is that this line of evolution, *i.e.* increase of space for the fore-brain without much relative lengthening, even possibly with relative broadening, occurred somewhere in the mountain zone of the Old World, and most probably in Asia Minor or the W. Persian area or near by. Why is this region suggested ?

Among the highlands of S.W. Asia, Anatolia and Armenia have long been the home of one of the most remarkable developments of broad-headedness, with specialisations not shared to any extent by the Carpatho-Alpine or by the Irano-Pamirian broad-heads. The two groups are like one another in several ways, and it may be suggested that they are survivals of a stage of the development of broad-headed types which has been passed and left behind by the people of the Tauro-Armenian region. If this be so, on the principle of wave-spreads from an evolutionary centre which Clark Wissler[27] has so well expounded for cultural anthropology, one may risk the suggestion that the broad-headed type of modern man had his first home not far from Asia Minor.

So far, the only suggestion about physical character of these people has been that, among men using the masseter muscles to a greater extent

[27] Wissler, Clark. 'Man and Culture,' 1923 ; 'The Relation of Man to Environment in Aboriginal America,' 1925.

than the temporals, the skull would be freer to expand along both diameters instead of almost exclusively in length. More chewing and less tearing and pulling would less definitely pull the jaws lengthwise. More power for chewing would be gained by growth in length of the ascending ramus of the jaw, and this added growth is a feature of most broad-headed types. Increase of power of the masseters above a certain amount can be secured probably only by increased width of the malar bones, and thus by increased width of the face. If the face and jaws tend towards width rather than length the same tendency is likely to show itself in the head. After men had attained the upright posture a strong forward projection of the face would have to be balanced by a backward projection of the head; on the other hand, a reduction of such a forward projection would allow the reduction of the backward projection. On the whole, then, with the changes indicated, it is possible to think that men among whom chewing was far more important than tearing and pulling with the jaws, might find their normal head-growth leading rather to an increase than to a decrease of relative cranial breadth. Broad-headed people spread very early into Europe, and their skulls are known from Ofnet and Mugem. Some of the Ofnet skulls show a frontal region which suggests dolichocephaly, while the parietal region demonstrates brachycephaly; this is a natural feature in skulls of early date if we remember the restrictions operating in early times on frontal growth in breadth.

There has been no attempt to argue that emphasis on chewing rather than on tearing and pulling by the jaws has led to a change from dolichocephaly to brachycephaly. The suggestion has rather been that modern types of men may well have started medium-headed with indices not very different from those of ancient man (the frontal torus of Neanderthal types not being counted with the skull for purposes of measurement). On this has been built up the idea that growth would express itself in form changes which would on the whole tend towards growth in length in some cases and more towards growth in breadth in others.

The skulls of early modern men, in which the growth in length is fully seen, rarely have a cranial index of more than 72, and this gives, for them, an index not above 73-4 on the living head. Specimens with indices below these respective limits form a much better-marked group than those below the '75' limit of dolichocephaly often quoted and used.

Skulls with indices 72 or so to 77.5 (say 73.5-79 on the living head) are a more heterogeneous group, including perhaps survivors of early types with increase of fore-brain space but only relatively slight increase of relative length. They probably also include cases in which there has been an evolution from long-headedness of the extremer type, thanks to the reduction of restraining influences of the temporal muscles during the period of growth.

No sharp divisions in a continuous series, such as that of skull forms, can be really satisfactory, but 72 and 77.5 on the skull or 73.5 and 79 on the living head would be more useful than the limits generally chosen.

Another factor seems to have operated in the evolution of the broader-headed types. The nasal chambers, as Thomson has pointed out, are

often large in broad-headed men.[28] In the broad-headed people of Asia Minor this largeness is emphasised in unique fashion. They have grown forwards and give the remarkable Hittite noses of the ancient reliefs and of the modern population. This suggests the accentuation of the median plane in more or less frontal growth, and this tendency is carried to an extreme in some peoples of Asia Minor and the Illyrian region with very high, small-crowned heads as well as very strong noses.

On the other hand, among the later spreads of broad-headed man to the high plateau of the Tarim, Mongolia and Tibet, we find a flattening in and deepening of the malar, giving extra strength and directness to the masseter muscles; and with this the nasal bones are naturally inclined to remain flat, so the space for the nasal chambers lies well in towards the brain instead of projecting far forwards. This gives an increased tendency to frontal breadth of the skull, resulting in the well-known rounded-head form characteristic of some peoples of this region. Here it should be noticed, first, that many people, especially towards the north side of the plateaux of Central Asia, do not show this flattening, but rather have prominent noses; they may well be drifts from the Pamirs or Anatolia. The broad heads of the high plateaux are generally brown or yellow-brown in skin colour; this is to be correlated first with the retention of an ancestral brown tinge by people who remain exposed to marked glare of sun and snow, and second with the thickening of the dry superficial layers of the skin and the sinking of the blood-vessels into the deeper layers of the dermis, both protective devices in a region where the cold anti-cyclone of winter is so highly developed. Those who are interested in correlations with activities of endocrine glands will note that dryness of skin and flatness of face ('Mongolism') have been said to be associated in the West with unusual lowness of pituitary secretion. Excess of pituitary, on the other hand, produces acromegaly, including over-development of the mouth, brow-ridges, &c., and it can be corrected to a remarkable extent by giving doses of thyroid extract. Our knowledge of the endocrines is still in its infancy, but it seems likely that the proper balance of these secretions is one prime need for normal growth, and that balance seems to be somewhat different in different regions. It would seem, at the moment, that the influence of pituitary relatively to thyroid is greater in tropical Africa than it is in inner Asia, *i.e.* in a warm, rather moist, than in a cold, dry climate.

To sum up as regards broad-headed men, I think the type originated somewhere in the S.W. Asiatic mountain-country and that broad-headedness spread both north-westward as the mountain regions of Europe cleared themselves of glaciers, and north-eastward as Turkestan, &c., became more habitable. On the one hand, I think that the development of broad-headedness, with accentuation of the median plane, has gone much farther in Illyria and Anatolia than among the broad-headed people who have spread, whether to the Alpo-Carpathian region on the north-west or to Turkestan, the Pamirs, and Gobi on the north-east. On the other hand, I think that some of the broad-heads entering the region of

[28] Thomson, A., *Journ. Roy. Anthr. Inst.*, xxxiii., 1903; also *Proc. XVII Internat. Med. Congress*, 1913. Thomson, A., and Buxton, L. H. D., 'Man's Nasal Index,' *Journ. Roy. Anthr. Inst.*, 1923.

the high plateaux of Asia have undergone a further course of evolution in features affecting skin, cheek-bones, nose and skull. May we not look upon the very variable extra fold of the upper eyelid as a more or less mechanical adaptation closely linked with the flattening of the malars? Once it had begun, it might well be developed farther by use and consequent growth in the individual, as it is of value as a protection against glare.

Before leaving this part of the subject it may be permissible to add a few words concerning 'Mongolism' in Western Europe. It occurs sporadically in the Celtic fringe of Britain and France, as Beddoe noticed, and there was little that he did not notice! It may conceivably be there because of some extension into those areas of people from North Europe in early times; the influence of Arctic cultures on the West in epipalæolithic times is now generally acknowledged. But it may also be correlated with some alteration of endocrine balance occurring among inbred populations, for such populations are very apt to show such disturbances of balance as we infer from the distribution of goitre, cretinism, &c.

If 'Mongolism' in the West is associated with disturbance of what may be called a regional balance of development usually obtaining there, and is thus sometimes, but not by any means always, associated there with mental peculiarity or defect, this is no ground for arguments such as have been rather frivolously advanced about fancied inferiority of Mongol types generally. The regional balance of development may well be different in Eastern Asia.

To return to our broad-heads of the high plateaux of Central Asia, with their dry yellow-brown skin, almost hairless bodies, and in some cases flattened malars and non-prominent noses, the idea is suggested that these high plateaux, for reasons some of which have been indicated, became a region of evolution along the lines mentioned, and became such, probably, relatively late in the spread of mankind. Around this region, as the general hypothesis would lead us to expect, we usually find less broad-headedness, whether we look north-east or east or south-east, though south-eastwards there are, it is said, more broad-heads than in other directions. Towards the east, that is, in North China, the brown pigment of the skin becomes much less pronounced, but the skin remains dry and to some extent yellowish, while south of latitude 30° with the stronger insolation the brown pigment remains, though there is apparently less extension in this direction of the tendency to flattening of the malars. Towards the north there are traces of long-heads, as has already been said, in the Arctic north-east; but the Arctic north-west, towards Europe, must long have remained peculiarly forbidding, and the spreads in this direction are of broad-headed types with most of the accessory features, including the facial flattening. Under conditions of Arctic glare the pigment is, naturally, retained, and the dryness and hairlessness of the skin are also characteristic. Beyond the north-east, in America, are broad-heads, especially, as one would expect, on the American highlands and on the Pacific side.

These few indications concerning the great zone of the broad-heads and its fringes, must suffice in a sketch of this length, and we turn from them to a review of the long-heads of the north-western quadrant and of certain other regions.

XI.—The European Quadrant of the Old World.

In the Mediterranean basin, it has been suggested, we have from Aurignacian times onwards extreme long-heads, together with perhaps modified or unmodified survivors of the long- but not very narrow-headed type illustrated at Cro Magnon. It is quite possible that these ancient peoples were brownish skinned, and that the Grimaldi element was an important one, for, though we have only the two specimens from Grimaldi and possibly a woman from Mugem as ancient examples, there are numerous traces of an analogous type in present-day populations. The Predmost-Combe Capelle group may also have been important, but was apparently more characteristic farther north, in spite of Giuffrida Ruggeri's wish to associate it with Ethiopia. The low long-head from Mechta el Arbi may represent another element. In the western Mediterranean basin, with climatic improvement and beginnings of food production and settlement, it would seem that a balance of development was reached giving a head long, but not so long nor with such strong pressure of temporal muscles as some of those of early times, with olive or pale complexion and moderate nose and face. Maturity comes earlier, apparently, with settled life in this climate than farther north, or it may be that the girls marry early. With this early maturity may be associated diminution of brow development, also correlated with decrease of temporal muscles, and relative slimness of build. In the desert of Arabia, with its sun-glare and its sharp night-air, we find more skin-colour and more prominent noses. In North Africa, betwixt and between, we have old characters persisting, but with tendencies, on the whole, in the same direction as in the western Mediterranean, though more skin-colour is a feature. Thus one may look upon Mediterranean, Semitic, and so-called Hamitic races as fairly late regional specialisations among the descendants of a mixed lot of types of early long-headed and very-long-headed man.

In North-West Europe the Predmost-Combe Capelle group seems to have been important, along with probable traces of the Cro Magnon group. The penetration of food-production schemes into this region was apparently slow, and ancient British and Scandinavian skulls, for example, give strong indications of the persistence of old characters. With the growth of settlement and related changes came, it would seem, reduction of the jaws and their muscles, and this, in a region which encouraged long continuation of growth, led to the increase of tallness and to the development of a rather large regularly curved skull, preserving the brow-ridges to some extent, but developing nose and chin and the sagittal curve generally. Thus one may look upon the Nordic Race as a fairly late regional specialisation, probably on the European loess as well as near the Baltic, of the survivors of late Palæolithic men.

Britain belongs fully neither to the north-west nor to the western Mediterranean region, and, while it shows types fairly closely linked with the specialisations of both these regions, it also shows as its most characteristic element a fair-skinned but rather dark-haired long-head who, however, has a larger nose and a taller stature than is typical of the west Mediterranean. This fundamental British type is most likely to be a descendant

of early immigrants, who had not as yet fully specialised in either the Nordic or the Mediterranean direction. It should be noted that this view in no way denies or controverts the idea of the distinctiveness of Nordic and Mediterranean races, as has been suggested by one or two critics.

In both the Mediterranean and the Nordic area, and in the British too, it is thus suggested that, as the compulsion exercised in early times by the temporal muscles diminished, the skull became freer to grow in breadth as well as in length. In the far west and north-west food production came late, when, presumably, fairly inbred types had been consolidating and fixing their characters for some time, or, one might also say, had been approaching a regional balance of development. Fair hair seems specially characteristic of some Baltic lands, and an analysis of Bryn's [29] catalogues of measurements for parts of Norway leads me to think that this character penetrated across Scandinavia to the Trondhjem fjord. His results show that more dark hair persists in Norway than has at times been supposed; and the fair-haired types are not by any means always very long-headed.

Turning now to the Indian side of the region of early modern man, it would be of the greatest interest could we reconstruct Pleistocene conditions in India. Was the heating of the Deccan then sufficient to give rise to the summer monsoon, and, if so, was it strong enough to create a continuous barometric gradient from the equator to the Deccan? If so, again, did the trade winds of the southern hemisphere sweep in and dominate the situation as they now seem to do? If so, finally, did the great swirl they set up work in the Indo-Gangetic trough, or rather to the west, as now? All these are questions I shall not venture to answer. Provisionally one may note that we have already spoken of survivors of early types of modern man in S. India, Ceylon, Malaysia, Australia, Tasmania, Philippines, Papua, some of them survivors of very early stages indeed. Without venturing any distance into the Indian race question, one may say that, broadly, the noses become more prominent as we go from the south to the north-west, and general profile development and growth along the sagittal plane is best marked among the north-western peoples, who spread, one might even say migrated, into India, according to most accounts, in the early part of the second millennium B.C., with the horse as a feature of their equipment. These are people among whom there was obviously, ere they moved far, a great liberation of initiative and a great call for energy. There are analogous spreads into Mesopotamia, even probably towards Europe at that time, all with the horse, and in later phases with the bronze sword, and all apparently of long-headed types with strong profiles. So the broad-headedness of the modern lowlands of Western Central Asia may well be in the main a fairly recent feature, and may be a spread of that character from the adjacent highlands analogous to a similar spread which appears to have been going on during the last millennium in Central Europe.

The extension of our Indian long-heads of various grades of profile

[29] Bryn, H. 'Trφndelagens Antropologi,' *K. Norske V. S. Skr.* 1917, No. 2 (1920); 'Mφre Fylkes Antropologi,' *Vidensk. Skr.*, 1920; 'Troms Fylkes Antropologi,' *Vidensk. Skr.*, 1921.

development to the East Indies and Polynesia, their inter-mixtures with earlier types and with migrants from the Chinese side, and the tendency towards the evolution of types aggregating characters from different ancestors are too special subjects for treatment in a general outline.

XII.—Concluding Considerations.

The intention of this sketch has been to suggest that we are approaching a stage at which it is possible to outline something of the process of race development. It bases itself upon the essential conservatism of heredity, and is in no way in agreement with the opinions of Franz Boas [30] as to rapid modifiability of type. I feel clear in my own mind that Boas' figures are quite inadequate to the support of his conclusions, both because of his use of averages and because of his argument from a single generation. At the same time I feel that modifications have occurred, and that we need to have working hypotheses as to the factors calling them forth and developing them on divergent lines.

It might seem that the thoughts expressed in this address lead direct to the Lamarckian position in evolutionary theory—changes of use of muscles, of jaws, and so on, being brought out repeatedly as influencing the racial resultant. This is a large topic to touch upon at the end of an address, but I should be sorry to give the impression that I was either blind to the problems or disposed either to extreme Lamarckism or to pure anti-Lamarckism. It seems to me that development is a resultant of the working of hereditary factors of an essentially conservative kind, and of environmental influences which have undergone modifications through changes of climate and vegetation and food, as well as through changes of social habit and infant care and so on. Man, a social animal from the first, has developed his social sense and social organisation, and with this has gone change of environmental influences in plastic infancy, changing in various ways the net outcome of the struggle of factors (and with it the struggle of the parts) in development.

Are we, then, forced to think of every baby as being moulded from a very primitive stage to its appropriate modern form solely by repetition of these environmental influences generation after generation? I think not. We could not experiment, even if we dared, for a modern English baby placed under palæolithic conditions from birth would probably die, with its mother, who would have to be treated in the same way for the sake of such an impossible experiment.

Changes of environmental influences are usually cumulative, for natural processes are essentially irreversible even if, as in climate, there is something like a cyclic scheme of change. The cumulative change may be said to draw out the course of development more and more from its original path, thus creating a state of internal strain. No two embryos can possibly be exactly alike, unless they be early stages of identical twins, and some of the hereditary units may well vary towards, others away from, a condition which would diminish that internal strain. Those varying so as to diminish the strain would probably grow best. So we have a theoretical possibility of variation of the germ, limping after variation

[30] Boas, F. 'Changes of bodily form of Descendants of Immigrants,' 1911.

of the soma, and in the case of man, whose development is so closely linked with varying balances of the influence of endocrine glands, the limping may be fairly nimble after all.

It seems to me that students of the physiology and morphology of growth are leading us away from both the more extreme Lamarckian and the more extreme anti-Lamarckian view towards a view that takes in many more considerations. The study of growth in children, pre-natally and post-natally, is a matter of urgent scientific importance, but a matter to be done patiently, lest, by taking arrays of children of varied types, even if all English, at various ages, we fall into error, as some have done recently. Every case, to be of real value, should be that of an individual child followed year by year. Any method of arrays presupposes a homogeneous population with one set of general growth tendencies, and such conditions are unattainable.

This attempt to outline an evolutionary, rather than a taxonomic, survey of the races of man naturally owes a great debt to Dr. Haddon; to W. Z. Ripley, who pioneered in the direction of historical interpretations; to Collignon, who saw a long generation ago that there were among us survivors of several ancient types of modern man; to Prof. Myres, to Prof. Elliot Smith's studies of human evolution, to many suggestions in the work of Prof. Sollas and Sir Arthur Keith, Dr. Hrdlička and Prof. Arthur Thomson, and also to both Prof. R. B. Dixon and Dr. Griffith Taylor, with whose stimulating work readers of this address will gather I do not altogether agree.[31]

A doubt persists in my mind as to the assignment of more than a somewhat limited value to taxonomic treatment of the question. It seems worth while to think rather of regional gatherings-together of physical characters.

A special attempt has been made to suggest the part played by the development of social life in the evolution of human physique, and the importance of parental care. These factors seem in particular to have led in certain circumstances to a vast liberation of individual initiative within our human societies, especially after the development of intercourse between groups.

We must speedily undertake more and more biological observation and measurement among ourselves, and we must exercise ever more care in treatment of our measurements. Averages of cases which are not properly homologous should not be made lest we mask the biological truth in mathematical abstractions. If our anthropological work can but go on becoming more biological, gaining insight into physiology, especially of the brain and the endocrine organs and their correlations with growth, I venture to think that Racial Study will develop great practical value for education, for the fight against tuberculosis and other diseases, and for race-

[31] Haddon, A. C., especially 'The Races of Man,' 1924; Myres, J. L., 'Introductory Section to Cambridge Ancient History,' vol. i., 1923; Sollas, W. J., 'Ancient Hunters,' 1924; Keith, Sir A., 'The Antiquity of Man,' 1925; Dixon, R. B., 'The Racial History of Man,' 1923; v. Eickstedt, E., 'Gedanken über die Entwicklung und Gliederung der Menschheit,' *Mitt. Anthr. Ges. Wien*, 1925; Smith, G. Elliot, *op. cit.*; Boule, M., 'Les Hommes Fossiles,' 1923; Martin, R., 'Lehrbuch der Anthropologie,' 1914; Taylor, G., *op. cit.*; Ripley, W. Z., 'Races of Europe,' 1899; Hrdlička, A., *op. cit.*; Thomson, A., *op. cit.*

improvement. Evolutionary Race Biology seems to me to be a hopeful sphere of work that may bring about a much-needed enrichment of public opinion on social questions, a diminution of race-arrogance, and a check on schemes that do not sufficiently allow for the mutual adaptations between diverse human stocks and diverse environments. I would ask for faith in the future of such work to bring out its great possibilities for nobler races with freer personal initiative in societies both more stable and richer in the things that are not seen.

SECTION I.—PHYSIOLOGY.

FUNCTION AND DESIGN.

ADDRESS BY

PROFESSOR J. B. LEATHES, F.R.S.,

PRESIDENT OF THE SECTION.

Among natural sciences physiology takes a place which in one respect is different from that taken by any other. It studies the phenomena of life, but more particularly the ways in which these phenomena are related to the maintenance of life. Anatomy and morphology are concerned with the forms of living organisms and their structure; biological chemistry, as distinct from physiology, with the composition of the material in which the phenomena of life are exhibited. The province of physiology, in studying the functions of these forms and of this material, is to ascertain the contributions that they make to the organisation of the living mechanism, and learn how they minister to the maintenance of its life. Function implies ministration, structure for physiology implies adaptation to function, what in a word may be termed design.

Ultimate analysis of the phenomena with which physiology deals leads to the fundamental distinction between matter in which life is manifested and matter in which it is not. Life is exhibited only in aqueous systems, containing unstable, perishable combinations of carbon with hydrogen, nitrogen, sulphur, phosphorus and oxygen, in the presence of certain inorganic ions, those which are present in the sea, the native environment originally of all forms of life; and the inalienable property that such matter exhibits when alive, and that matter which is not alive does not, is that these unstable organic combinations are for ever reforming themselves out of simpler combinations that do not exhibit this property, and do so at a rate which averages at least not less than that at which they break down. This power of self-reformation, spontaneous regeneration, operates not only when living organisms, cells or communities of cells are growing or reproducing their kind; the very maintenance of living existence requires by definition that it should persist. In the absence of water the living process may sometimes apparently be suspended for a time, as it may be if the surrounding watery medium is immobilised by cold; it is a question whether this is anything more than a retardation to a rate of change that is imperceptible by the ordinary methods of observation, and a question how long such suspended animation is possible where it is possible at all. It is only where water has the kinetic activity of the liquid state that spontaneous regeneration of living matter can in general proceed, and then it must, for when it ceases the unstable material ceases to live.

Chemical analogies for this power of spontaneous regeneration, if such exist, can only exist in part; in the present state of our comprehension

of it, certainly, it is hazardous to try to trace them. The attempt so commonly made to trace one between the growth of living matter and the growth of crystals in a saturated solution, it is safe to say, is in so many respects on the wrong lines that it is merely misleading. Crystals are not alive. The molecules that constitute the crystal are set in solid formation; so long as the crystal exists they are stable and unchangeable. These molecules collect on the growing crystal, but they exist ready-made in the surrounding solution; they do not come into being by the influence of the crystal; they are themselves so constituted as to take up a set position in relation to each other and to those already ranged side by side in the crystal, as soldiers on the drilling-ground at the word 'fall in'; they are available because the solution is kept saturated by the dissolving of smaller but similar crystals that for physical reasons are more soluble in the solution than the larger ones. In contradistinction to this, the molecules that enter into the composition of living matter exhibit the phenomena of life only when permeated with water molecules exercising the kinetic activity of the liquid state; they are unstable and perishable; the added molecules, some of which even during growth and all of them at other times, serve but to replace those that perish, do not exist ready-made; they come into being only in conformity to the pattern and under the influence of those already in existence, a pattern that these alone can use; and they are formed out of material that is chemically different from them.

Let us for a moment consider what this spontaneous regeneration implies. Of the various chemical components of protoplasm, proteins are generally considered the most important, often the only important, ones. The elucidation of the chemical principles upon which the structure of proteins rests, which took place about the beginning of this century, was, like the neurone hypothesis of the structure of the nervous system, an advance the magnitude of which only those perhaps can appreciate who began the study of physiology well back in an earlier one. For a time it seemed in each case that the problem was solved and all that was to follow was simple. Those were great days. The best-known varieties of proteins, when detached and uprooted from the place where they grew, consist of chains of about a hundred, sometimes nearly two hundred, links. Each link is an amino acid coupled by its acid group to the amino group of one neighbour and by its amino group to the acid group of its other neighbour, a molecule of water being lost at each linkage. There are not more than about twenty different amino acids, so that some of them must occur several times in the chain; in some kinds of protein one amino acid may occupy thirty or forty of the hundred places in the chain. In any such isolated protein it is probable that the order as well as the proportion in which each amino acid occurs in the molecule is fixed, and it is this specific order and proportion that accounts for the specific character and properties of the protein. What could be simpler? And only yesterday all was so obscure.

It is not recorded that in the rush of this advance anyone stopped to reflect what number of formations such a protein might still possibly have. Supposing it were a chain of only fifty links, a very simple case; if all the links were different the number of possible permutations is

denoted by the innocent-looking symbol $\underline{|50}$. If, instead of all being different, one kind of link recurred ten times, the number would be reduced to $\underline{|50} / \underline{|10}$. If, in addition, there were four that recurred four times and ten that recurred twice, it would be further reduced to

$$\underline{|50} / \underline{|10} \times (\underline{|4})^4 \times (\underline{|2})^{10}.$$

It would now consist of a chain of only fifty links, of which there were only nineteen different kinds, and the number of different arrangements of its parts would be about 10^{48}. Astronomy deals with big figures. Light, it is said, takes 300,000 years to travel from one end of the Milky Way to the other; this distance expressed in Ångstrom units, 10,000,000 of which go to a millimetre, would be less than 10^{32}. So far are we from knowing the structure of protein molecules. So far are we from knowing what variations in disposition of the parts in such a molecule may not occur without our being within a measurable distance of detecting them. For if the number of possible varieties of a protein whose molecular weight is known, and known to be exceptionally small, and which contains the several amino acids in a known proportion, is as great as this, the number that is possible when that proportion may be changed is practically incalculable, each change in proportion being capable of a number of new arrangements that could be calculated, as was done for our hypothetical case.

But in the living cell where these chains are put together each link must first be fashioned and then forged into the chain; unfinished chains *in statu nascendi* must exist which our analytical methods can never detect. In such unfinished chains the order presumably in which the amino acids are linked up is observed, but the proportion must be different from that in the finished product; for in a chain of nearly a hundred links a particular amino acid, cystine, for instance, may occur only once.

Now it is possible that the analogy of crystal formation may be applied to the reproduction of the characteristic order in which the linkings occur, and that the parts out of which a new chain is to be formed may be collected and brought into position alongside of the corresponding parts of an existing chain by forces that are similar to those that determine the latticed relations of atoms in a crystal. But something more than this is required to account for the linking up of these links by the loss of water, and still more for the fashioning of the links themselves. In plants all varieties of amino acids come into being as required; in animals, it is true, some must be supplied ready-made in the medium in which the proteins grow; but even in animals some of them can be formed from material of a totally different nature.

Wherever this is the case we have to suppose that it is by selective emphasis of certain otherwise unemphasised but possible arrangements of atoms or groups of atoms, evidence for the occurrence of which under similar conditions in the absence of life is generally not obtainable. Specific catalysed syntheses must co-operate with the forces that merely sort out and place in proper order the assembled parts, and must fashion for them the particular links that they need at each step. Specific catalytic agents playing an important part in cell chemistry are familiar in the enzymes found in digestive secretions and also locked away within the cells themselves. There is much to support the idea that such agents act by

modifying the chaotic, indeterminate, kinetic agitation of certain kinds of molecules in their immediate neighbourhood in such a way that the relative positions in space of groups capable of reacting with one another tend to become those in which reaction is likely to occur and to occur in conformity with a certain pattern. The peculiar thing about the chemistry of living matter is not that the reactions that are characteristic in it are novel, but that in the rough and tumble of ordinary liquid systems their occurrence is almost infinitely improbable. Where there is life, circumstances exist which make them the rule. Anyone conversant with work in animal metabolism can supply many illustrations; for instance, it has been shown that in a simple solution of the amino acid alanine traces of methyl glyoxal occur; in the animal body there is reason for thinking the reaction may become practically quantitative. Forces which determine the relative positions of adjacent foreign molecules and so affect their behaviour are something to which there is no analogy in the growth of crystals in a saturated solution.

Moreover, if the forces that determine the reproduction of a certain order in the arrangement of the parts of a protein are similar to those that determine the lattice pattern of a crystal, the crystals with which the comparison is made are solid, and life is manifested only in liquid aqueous systems. The analogy should rather be with the formation of liquid crystals, a phenomenon that is itself as yet too unfamiliar to shed common light on the obscurity of spontaneous regeneration. The ordered disposition of the ultimate components of protoplasmic systems is such as to leave play, generally but little checked, for the fluid properties of water, and in some modified degree too of molecules and ions dissolved in water. Even a solid jelly may include within its protein framework a hundred times its weight of water in which diffusion is free to take place almost as if the framework were not there, and protoplasm, with commonly twenty times as much protein in it as this, more often resembles a fluid of varying viscosity than a solid gel, which means that the great protein chains float and drift in the whirlpool of kinetic agitation, observing, it may be, so far as is possible, certain unstable relations to their kind, but with no rigid fixity. It is commonly felt that the behaviour of unicellular organisms makes the hypothesis necessary that there is an insoluble surface layer that keeps the watery contents of the cell from dispersing in the water that surrounds it. Much experimentation, and no lack of speculation, has not made clear what the nature and structure of this limiting layer is. It may be that the flexible cohesion at many alternative points between clinging floating chains of amino acids, the innermost of which are made fast to the nucleus, may go some way to maintain the identity of the cell and prevent its contents from scattering.

But in the chemical make-up of protoplasm, proteins, the most abundant component, are not the only ones that are necessary. Pre-eminent among the others are the nucleic acids. When we consider what has been learnt of the behaviour and of the chemical composition of the nuclear chromosomes, and that according to Steudel's reckoning the nucleic acids form 40 per cent. of the solid components of these chromosomes, into which are packed from the beginning all that pre-ordains, if not our fate and fortunes, at least our bodily characteristics, down to the colour of our

eyelashes, it becomes a question whether the virtues of nucleic acids may not rival those of amino-acid chains in their vital importance. From Steudel's figures it can be reckoned that there are about half a million molecules of nucleic acid in a single sperm-cell of the species with which he was working.

But in addition to nucleic acids there are also strange compounds of higher fatty acids containing suspiciously significant groups, identical in their general character with those found also in nucleic acid, namely, phosphoric acid, organic bases and sugar; and besides these there are the mysterious sterols. All of these are frankly insoluble in water, and yet have in some part of their composition features that make them not indifferent to water or even to the molecules and ions that exist in true solution, in the liquid state, within the cell. The physical condition of these insoluble substances in the aqueous system of the cell is still little understood. All that can be said with certainty is that they must modify its homogeneity even more than the long floating chains of amino acids, however much these may be linked together one with another. If the characteristic behaviour of living matter is rightly regarded as due to the order that it introduces into the movements and spatial relationships of foreign molecules in its vicinity, then these insoluble components may well be expected to play a leading rôle by forming films and surfaces that permeate its texture and delimit its parts.

Such an analysis of the chemical meaning of material life viewed in the light of scientific facts has to be largely an exercise of the imagination, but it may present itself as an intellectual necessity. If it is right to regard the power of spontaneous self-regeneration as the distinctive property of living matter, it is not intellectually possible to be content with a phrase and dismiss it. A phrase is itself an image, and an image, however shadowy, has parts and dimensions. Those who feel it an intellectual necessity to explore unexplored lands cannot procure maps, but that does not justify their setting out with no forethought or reasoned plans.

The beginning of life, if it is an intellectual necessity to trace this, would thus appear to have been in the coming together of atoms of certain elements in such a pattern that this power in its simplest form resulted from its design. Some might call this event fortuitous, others the predictable outcome of the inherent properties of those elements, the inevitable operation in the course of time of the laws of chance. Those who call it fortuitous may go so far as to regard the whole history of life as fortuitous, and give priority to the concurrence of the atoms over the properties and functions that are revealed by the concurrence. The others may look on life as the fulfilment of the destiny of these elements, and give priority to the potential properties of matter over the concurrence which was no more than their epiphany.

If this analysis is approved, and the distinctive property of living matter, the power of self-regeneration, depends upon the power of limiting the movements and directing and controlling the spatial relations of surrounding molecules so as to modify their chemical behaviour, it is the exercise of this same power that leads to the formation of substances such as starch, glycogen and fats; and in so far as such substances contribute to the regeneration of the living matter, the power of forming them contributes

to its survival. Where energy is necessary for such synthetic rearrangements of adjacent matter—where, that is, the rearrangement involves coercion of atoms into positions of strain in which they have the potential energy of position which we call chemical energy—this energy may be derived from the radiant energy of the sun or from the combination of oxygen with adjacent organic matter. In the latter case the combination is again a manifestation of the power of ordering the disposition of surrounding molecules and directing their movements so that they behave as in other circumstances they would be but little prone to do. The energy so liberated, besides contributing to the formation of new living matter or of the material to be used in its formation, may serve in other ways to promote the processes by which life is maintained. It may accelerate them by imparting increased kinetic activity or rise of temperature, or may bring about movements that are resisted by external forces, and so enable the living system to do work.

This is all merely a restatement of the commonplaces of biology, necessary only as part of the attempt to correlate them physiologically with the fundamental property of that which is alive to regenerate itself at the expense of material that is not alive. This faculty implies the power of introducing order into the chaotic movements of adjacent matter in conformity with patterns that it possesses. It is a faculty resident in material that is capable of incalculable variation. The number of permutations of its parts that are possible without affecting the results of such analysis as is practicable defies calculation. Their calculation, were it possible, would lead to figures that are so large as to mean no more than the dimensions of the universe. Some of these permutations confer synthetic powers which others do not. When they appear, are they not what biologists call, for short, mutations ? But when they appear, if the retain the power of self-regeneration, and if they minister to its maintenance, they will *ipso facto* survive. For whatever promotes persistence of this power must itself survive.

A disposition of matter in molecules or aggregates, unstable and incalculably variable, that has and retains the power of determining the disposition of matter not yet so disposed in such a way as to conform to its own disposition or to patterns which help it to exercise this power, is all that must be premised for the whole of evolution to follow. Variations that do not or cease to contribute to the retention of this power do not survive. The condition of survival is ministration to self-regeneration ; that is, to the maintenance of life.

Before the days of vertebrates, in pre-Silurian time, an unstable variation in the disposition of atoms and organic combinations of atoms occurred in certain types that was mainly protein in character, a protein to the making of which little short of 200 amino-acid links must contribute. Coupled to this protein, which probably is not the same in all species of animals in which it is found, is another group containing iron that is probably always the same. This group is of remarkable nature, and is closely related to one that occurs in the far older substance chlorophyll. This complex substance, hæmoglobin, had the power of attaching to itself two atoms of oxygen for each atom of iron that it contained in such a way that it could be readily detached and made

available for effecting oxidations. Such was the service that this variation rendered that it is safe to say that without it there could be no vertebrate creation. It is this service that has made it possible for it to survive to this day, when in the human species alone it is being produced at the rate of about 10,000 tons a day. The story of the service of chlorophyll would, of course, be more remarkable than this.

Natural selection applies to the survival of the chemical forms of living matter as it does to complex living organisms. These forms, infinitely protean in their variety, survive and persist in so far and so long as they minister to its self-regeneration. It is the principle of survival by service. Function alone gives permanence to structure. Structure without design is a pathological excrescence that has in itself the seeds of its own destruction. What does not minister to self-regeneration has no enduring share in life, for self-regeneration is the key to life.

Why is it that what may be termed official physiology takes so little cognisance of the doctrine of evolution? These branches of biological study appear to follow courses so exactly parallel that they never meet.

The doctrine of evolution digs down into the foundations of scientific philosophy. If a physiologist addressing physiologists ventures to say anything on this subject of supreme appeal to all biologists it must be in exaltation of the work of those who have approached it from the morphological side, and it may be in hopeful anticipation of the ultimate share in the elucidation of some of its problems to be borne by physiology.

On the part that function plays in the determination of structure it is to be supposed that physiology will ultimately, at any rate, have something more to say. May I submit to the consideration of physiologists certain points in the physiological development of the machinery of the body where, unless I am mistaken, it is possible to detect the operation of function in determining the design of the machine? The properties and behaviour of cells result from the properties and behaviour of the material composing them. When a muscle-cell contracts this is, in general terms, a reversible rearrangement of its parts in response to some alteration in the distribution of forces within or about it due to a disturbance from without. Such reversible reaction to adequate disturbance is a property common in the material of which living cells are composed. In addition to this reversible type of reaction there are irreversible reactions which are characteristic of other kinds of cells, and it is what we call connective-tissue cells that I would ask you to consider. There are several kinds of connective-tissue cells, but they are alike in that they produce and discharge into their vicinity material of a characteristic composition; in some of the commonest this material is chemically collagen, the substance out of which gelatine can be obtained. In course of time these cells come to be embedded in the material which they deposit about themselves and so form one kind of connective tissue. Cells capable of behaving in this way are found, however, which have not yet exercised their faculty; these fibroblasts are then undifferentiated wandering cells that have found no abiding-place in the community in which they have their birth. What it is that makes them settle down and start producing the material in which they come to be embedded has never yet been determined. But the most striking structures to which they give rise are the tendons and

aponeuroses that make the muscles fast to the bones, and the ligaments that bind the bones to one another. The material that they deposit is composed of inextensible fibres that lie, in the case of tendons at any rate, so exactly and exclusively in the line of the resultant of the tension set up in the muscle to which they attach themselves, that it is difficult to believe that the disturbance which starts them producing their characteristic secretion is anything else than the pull exerted on them by the muscle-fibres to which they are attached; the recurring external disturbances that produce reversible states of tension in the muscle, indirectly producing in them an irreversible reaction, which consists in the discharge of material that by its inextensibility can transmit the tension along the line of the force that provokes its deposition. In their simplest form cells of this kind deposit the wavy fibres in areolar tissue which, when straightened out under the action of a displacing force, set a limit by their inextensibility to the dislocation of the part first affected, and so distribute the action of the displacing force over surrounding areas. It is interesting to note that the origin of cells of this kind has been traced to the mesothelium cells that line tissue spaces and serous cavities, the clefts that make the gliding displacements of parts over one another possible. The deposition of fibrous material seems here, as in the tendons and ligaments, to be the result of reaction to the recurring disturbances set up by displacements, such, for instance, as those of the lungs, the alimentary tract, the heart and pulsating vessels, and the deposition occurs in the line of strains set up by the displacing forces. The service rendered by this behaviour of the cells is that the fibres which they deposit, in virtue of their inextensibility, limit the extent of displacement at any one point by distributing it to surrounding parts.

The other component of areolar tissue, the elastic fibres, is similarly produced by other cells. These fibres take a straight course between their attachments; displacements in the line of their deposition are rendered possible by their stretching, and are recovered from by their elasticity.

The contribution made by such cells to the fabric of the body appears to result from the recurring operation of disturbances, to which they react by depositing fibres along the lines of disturbance.

More striking are the properties of cells upon which the formation of the skeleton depends. The cells that make bone not only secrete fibrous collagen, they also encrust the fibres with insoluble lime-salts, and it has long been subject of comment that the rigid bone that results always comes to lie in the line of prevailing strains and stresses. The analysis of the structure, for instance, of the head and neck of the human femur, by Wolff and others who have followed him, shows how strictly this is true. Calculations prove that no particle of bone lies anywhere but where the strains dictate. We can predict with certainty, it seems, that it will be found that bone-cells are composed of material that in reacting to physical forces directs, in constant relation to the line of action of those forces, the deposition of the substances which make up this connective tissue. Bone can only arise where strains and stresses set up this reaction, and the greater the strain or stress the denser the deposit. When a bone is fractured many bone-cells are dislodged, and, in the abundance of nutriment that ruptured vessels supply, these cells, released from their

imprisonment, multiply. At first the force of gravity and the twitching of muscles acting on the soft semi-fluid tissues between the broken ends of the bone supply stimuli that are indeterminate in direction, and such reaction as occurs results only in the formation of loosely ordered calcareous fibres ; but even this soft callus gives some degree of rigidity, sufficient to restrict the strains gradually to more and more clearly defined lines along which in proportion a stronger reaction can take place. Once it is established that bone corpuscles react to strain and stress by discharging collagen, the intimate spatial disposition of which, as well as of the lime-salts with which it comes to be encrusted, is determined by the directing forces to which it is exposed, and once it is recognised that the law of spontaneous regeneration requires that this reaction will persist in proportion to the prevalence of these forces, not only must the gradual replacement of callus by appropriate permanent bone necessarily follow, bone in which no particle persists except it be in the line of constantly recurring stress and strain, but it will also necessarily follow that the position of every spicule of bone in the skeleton, cancellous or compact, is the expression of a physiological reaction to the forces of gravity and muscular tension. The evolution of the machinery of the connective tissues seems to be not entirely the result of natural selection and the survival of individuals in which this machinery chanced to be of appropriate design. The appearance in early vertebrates of the material that is characteristic of the bone corpuscle seems to have ensured that skeletons would take a shape determined by the direction of the forces to which these corpuscles were exposed, and that the formation of this skeleton is as much a reaction to recurring stimuli as are the reflexes, composite movements, and postures characteristic for the species.

This conception of the way in which the vertebrate connective tissues take their shape transfers a large share of the development of the bodily form back into the nervous system, in which the machinery is stored that directs and determines the habitual movements and postures that in reaction to external disturbances are specific. A physiological account of the evolution of the nervous system, one certainly that is based on the chemical constitution and chemical behaviour of its component parts, must seem almost infinitely remote from practical investigation. But the work of Pavlov has made one thing clear, that by a physiological reaction in it machinery may come into existence which did not exist before. The repeated occurrence of a disturbance at times that are uniformly related to the normal operation of existing machinery results in the acquirement of a new reaction which must require machinery that is new. It is rendered probable, if not proved, that this new machinery is situated in what may be called the growing point of the central nervous system, the cortex of the cerebral hemispheres, the part where all is not cut and dry, where cells retain more of the properties of the developing neuroblasts, the properties that enable them to grow out through the embryonic tissues along courses that make it certain that the maturing organism will behave in a manner true to type. In the formation of a conditioned reflex two events are made to occur in the cerebral cortex at times which are uniformly related to one another ; one of these events, from the constitution of the nervous system, necessarily results in a certain activity of some

muscle or gland, the other has been hitherto in no way related to such a result; after many repetitions of the association of these events it is found that that one which previously had never resulted in this particular activity, comes to have this result as certainly as the other.

The sight and smell of food in any hungry animal results in the secretion of saliva because the cells to which the effect of these visual and olfactory stimuli is referred are anatomically connected with cells that set the salivary gland in action; the cells on which some particular sound takes effect are not anatomically connected with them, and this particular sound has therefore no effect upon them. But with the establishment of the conditioned reflex the anatomical connection comes into existence. As a result of a functional reaction of nerve-cells to disturbances in other nerve-cells with which they were not previously anatomically connected, a structure appears which is indistinguishable so long as it lasts from the structures that constitute any other reflex arc. The conditions that determine its persistence or effacement have been, and are being, studied as thoroughly as were those which allow it to appear. The outcome of these studies must be of incalculable importance in evolutional physiology. They are being watched with the keenest interest doubtless by all biologists, but more especially by those who believe that physiology has to take a much bigger part in the solution of some of the fundamental difficulties of biological science than it has been able to take in the past.

But if and when it is possible to trace the origin of structures to functional reactions of cells, and to reactions that depend upon the chemical properties of the cell substance; and if and when this is possible not only in the connective tissues, but also in the nervous system, the functions of which have so controlling an influence on the operation of every part of the body; until it becomes clear that the results of changes in such influence reappear in succeeding generations, the study of functions can have no bearing upon the ultimate problem of biology, the evolutional history of life upon the earth. Pavlov communicated to the last International Congress of Physiology in 1923 some results of experiments that he had done upon this subject which, when confirmed, would electrify the atmosphere. Conditioned reflexes that are established only after many—eighty or a hundred—repetitions of the associated stimulus, in each succeeding generation require fewer and fewer repetitions, and in the fourth may be established after only four. In April of this year he wrote to say that owing to other work he had not been able to give the necessary time to confirmation of these results. We are content to wait.

In the great question whether characteristics developed in the life of an individual have any influence on descendants, experimental evidence must come slowly. In what is called parallel induction a step has been taken which is probably of greater importance than is generally conceded. External influences that affect the bodily characteristics of an organism affect also the germ-plasm in such a way that these characteristics appear in the first, and even, in a less degree, in the second generation, born after the external influences have ceased to operate. While such experiments furnish evidence only of a temporary change in the properties of the germ-plasm, one that may be put down to the lodgment in it of unassimilated foreign matter that is gradually eliminated, the fact that the eternal

germ-plasm has been shown to be subject to temporal influences must not be belittled. A true mutation is not eternal. Our descendants may be able to dispense with hæmoglobin. Whether the hereditary melanism that in certain moths, it is said, can be induced by food infected with manganese is something more than such parallel induction, I hope there may be some present who can say.

Physiological inquiry is a stream that has many sources; its waters gather from quarters far removed from one another. A marvellous meeting took place in the early years of this century when the forgotten experiments of Mendel came to the surface again, and found corroboration in the cytological studies that from about the same time had pursued their slow, obstructed way above-ground in the endeavour to elucidate the changes in the nucleus of maturing germ-cells. In a resting germ-cell the chromosomes form an even number, characteristic for the species; they consist of half that number of pairs of homologues, one of each pair descended from the paternal element in the last zygosis, the other from the maternal. At one of the cell divisions by which the germ-cell gives rise to the mature gamete, with half the characteristic number of chromosomes, there occurs a segregation of the two members of each pair so that they pass into different gametes; the exact cytological equivalent of Mendelian segregation of allelomorphic pairs of characters. To-day the study of genetics and of the 'topographical anatomy of the chromosomes,' with its 'groupings' and 'crossings over,' seems to call out for chemical assistance. It may be that in the lifetime of some of us those confluent streams of thought and experiment are to be joined by yet another that rises in the vast, remote, and, as it must appear to some, muddy swamps of physiological chemistry; and it then, forgetting its 'foiled, circuitous wanderings,' will form with them a 'majestic river, brimming and bright and large.'

PSYCHOLOGICAL ASPECTS OF OUR PENAL SYSTEM.

ADDRESS BY

JAMES DREVER, D.Phil.,

PRESIDENT OF THE SECTION.

A well-known American authority on the treatment of young offenders quotes with approval the words of the girl who said to her judge: 'You and your officers are here to do your duty, and I suppose you are going to send me away, but before I go I want to tell you one thing—you don't at all understand me.' The analogy of the patient and the surgeon is not quite a fair one, but it is sufficiently close to allow us to use it for illustrative purposes. Think how intolerable the situation would be if the patient could with equal justice say to the surgeon: 'I know you have decided to perform a serious operation on me, but before you administer the anæsthetic I should like to say that you do not in the least understand my case.'

There is very real pathos in the girl's words to her judge; but it is not on the pathos of the situation that I would wish to lay stress, but on a common-sense view of the facts. Society, through its accredited representatives, acting under its recognised and established laws, is compelled to take action of the gravest import, affecting directly one individual member of society, and possibly affecting many other individuals indirectly, and this, in plain terms, without any clear and exact knowledge, either of what is being done, or of why it is being done.

No matter how deeply an individual has sinned, his sins do not free us from responsibility for our treatment of him, and for the consequences of that treatment on him and on other people. And we certainly do not divest ourselves of the responsibility by closing our eyes to the results of our action with respect to him. These are almost truisms, but like many other truisms affecting conduct, while we do not hesitate to do lip-service to their truth, we frequently ignore them in our practice. These considerations appear sufficiently weighty to justify an examination of certain aspects of our penal system from a psychological point of view. In fact they impose such an examination upon the psychologist as an imperative duty, demanded of him both as an individual member of society, who shares the responsibility of society for the results produced by its penal system, and as a psychologist, who, from his calling, is presumably better able than most to trace and evaluate these results. It is because I believe that

in this direction lies one of the greatest services the psychologist can render to the community that I have chosen as the subject of my presidential address ' Psychological Aspects of our Penal System.'

The root-idea in punishment as ordinarily understood is the infliction of some kind of disagreeableness, pain, or loss on an individual, because he has been guilty of some misdeed. There are thus two aspects—on the one hand the infliction of hurt, on the other hand the relation of this to some wrongdoing or crime. Originally any end to be gained by such infliction was scarcely conscious, if it existed at all—any end, that is to say, beyond the satisfaction of the anger evoked by the misdeed itself. The psychological source is to be found in the anger caused by the wrong. From this primitive source to the modern conception the evolution of theories of punishment, conscious or unconscious, may be said to have passed through four stages or phases. These may be designated the vindictive, the retributive, the protective or deterrent, and the reformatory or curative.

Let us consider the psychology of this process of evolution. To begin with, an individual who has suffered injury by the wrongdoing of another responds to the injury with the emotion and impulse of anger. This is satisfied by the infliction of some hurt on the wrongdoer. At the simplest and crudest stage of development—the stage where we have to deal with the mere instinctive impulse of the brute or the savage—the hurt inflicted on the wrongdoer may have no direct relation, either in kind or in degree, to the injury done, but only to the intensity of the anger evoked. Of course this is not really punishment in any strict sense. Nevertheless it is unquestionably the psychological origin, and it therefore marks the first stage in the evolution of what became punishment in the strict sense. This is the vindictive stage or phase. In so far as punishment at any time reveals the same emotion and impulse it represents this primitive vindictive stage.

Even in a very primitive social life, however, some crude notion of justice must very early act as a determining influence on the hurt that may be inflicted on another for some injury done. We are not at present concerned in the tracing of the psychological processes by which this notion of justice comes into being. It is only necessary to put ourselves in the place of the impartial onlooker to understand the psychology of these processes. So far as some notion of justice is a conscious determinant of the hurt inflicted on the wrongdoer by the injured individual, this hurt takes on the character of retribution, and punishment as such comes into being. This phase or stage in the evolution of punishment is the retributive phase or stage.

Another factor must have made its influence felt in a rudimentary way at a comparatively early stage. The notion of punishment must have involved a looking forward as well as backward, in the shape at least of a dim feeling that similar actions to that which has incurred it must be prevented in the future. There can be little doubt, that is to say, that at a comparatively early stage primitive society must have felt vaguely that punishment had a protective function, since by means of punishment of a culprit the individual and society were protecting themselves against the repetition of an injurious act.

The general line of evolution of our modern penal systems is thus clear. First of all we have purely vindictive action on the part of the injured individual. Then there is some sort of legalising—if we may use that word—of retributive action on the part of the injured, so long as this retributive action does not go beyond the limits of 'justice,' this being regulated by social law. Finally, recognising that punishment has a protective function as far as social life is concerned, society itself takes over the infliction of punishment, and a penal system is inaugurated. This stage or phase is the protective or deterrent stage or phase.

To leave the matter thus, however, would be to obscure important aspects and phases of the actual course of events, and could not fail to produce a misleading impression of the facts. Stages in social evolution are never clear-cut. Thus the development of the retributive view of punishment by no means involved the discontinuance in practice of vindictive punishment. Still less did the realisation of protection as the primary social function of punishment alter the practice which had been founded on the older and more primitive conceptions. Practice lagged a long way behind theory in this, as in so many other cases. The psychological explanation of the actual facts would appear to be that the crude emotion of anger remained the driving force behind punishment, though it was cloaked and obscured by other motives, and by various forms of rationalisation. After all, the reaction of anger is a natural reaction to an act which society agrees in reprobating. One leading authority on criminal law has, indeed, placed on record his conviction that it is 'highly desirable that criminals should be hated, that the punishments inflicted upon them should be so contrived as to give expression to that hatred, and to justify it so far as the public provision of means for expressing and gratifying a healthy natural sentiment can justify and encourage it.' I am afraid the learned author's thoughts have become somewhat mixed up in the latter portion of this statement. It sounds as if his rationalisation were not very satisfactory, even to himself. However that may be, it is certain that the realisation by society in theory that the function of punishment from the point of view of society was primarily protective did not prevent an almost religious sanction continuing to be attached to the *lex talionis*—' an eye for an eye.' This remained, in fact, an assumption at the base of all penal systems which no one seriously challenged. And it is equally certain that the protective function of punishment was frequently made the excuse, as in the writer just quoted, for continuing the practice of vindictive punishment—' for deterrent purposes ' was the usual rationalisation—even when it was quite evident that the psychological situation thus produced was often quite inimical to the ends sought. One need only instance the brutalising influence of capital punishment on society at large, and its inevitable tendency to increase the frequency of the crime of murder, during the period when it was the punishment also for less serious crimes, to show the kind of psychological situation which was created. Curiously enough the humaner—and, indeed, saner—attitude and practice of modern times in civilised countries were due far less to recognition of the fact that vindictive punishment for deterrent purposes was frequently an entire failure, than to the fact that the infliction of

pain and suffering on human beings became objectionable to the general sense of society.

The phase or stage of evolution at which we have now arrived is characterised, on the one hand, by the discontinuance, or the radical limitation, of what was virtually the primitive vindictive punishment in disguise, and, on the other hand, by the recognition of social punishments as possibly possessing a reformatory or curative function. We may speak, therefore, of the present phase or stage as the reformatory phase or stage in the evolution of social punishment. The actual situation, however, is somewhat complex. Practically punishment still rests, in law and in popular thought, on the retributive basis—the *lex talionis*. Theoretically it is recognised that from the point of view of society punishment is protective, and this is its primary function, and also, I believe, that society is not directly concerned with the retributive aspect of punishment as such, but only indirectly because of the deterrent effect of retributive punishment. Moreover—and this is the mark of the phase of evolution at which we have arrived—it is realised that, as far as the individual is concerned, social punishment may be made reformatory, and that the reformatory function of punishment is worth keeping in view, if only because reformation of the individual means protection of society against the repetition of the injury as far as that individual is concerned, always provided that the attempt to reform the criminal does not involve the sacrifice of the primary aim.

Though there is thus some conflict between the popular and practical view of punishment as protective and retributive and the theoretical view of punishment as protective and reformatory, practice is tending gradually towards conformity with theory. This is as it should be, since the theoretical view represents the view of the vast majority of those who have given serious consideration to the problems of social punishment. In what follows I am going to assume that there is general agreement with respect to three points: (1) that the punishments inflicted by society ought to be based on the protective and reformatory functions of punishment, but of these the protective is primary and fundamental; (2) that the retributive view of punishment is really a relic of an older theory of punishment that has rightly been set aside, though as a secondary determinant of the kind and degree of punishment the old *lex talionis* may still have to be reckoned with; and (3) that the reformatory view of punishment represents an ideal which a civilised community should always keep in mind, provided the true relation of the reformatory function to the protective is not forgotten.

The psychological problems of social punishment fall into two groups: on the one hand those involved in the effects of punishment on the individual who is punished, and on the other hand those connected with the effects of punishment on the community itself. Of course there is a repercussion on society of the effects on the individual, so that the problems of punishment are ultimately in every case social problems. Nevertheless we shall find it convenient to consider the two groups of problems separately in the meantime.

Consider, first, the problems arising in connection with the effects of punishment on the individual who is punished. So long as the retributive

aspect of punishment is placed in the foreground, the only psychological problems of serious import are those involved in the question of the responsibility of the offender. This question of responsibility is one over which medical and legal minds have long been at loggerheads. The source of this age-old controversy between lawyer and medical man lies primarily in the fact that the two use the word ' responsibility ' in entirely different senses. For the lawyer ' responsibility ' is purely a legal term, and the question of responsibility is to be determined on the basis of evidence germane to its legal meaning. For the medical man ' responsibility ' is an ethical term, and the question of responsibility therefore raises much wider issues. As the controversy develops it becomes more and more entangled, owing to the fact that the lawyer insists on discussing psychopathology and medicine, which he is not competent to discuss, and the medical man insists on discussing ethics, which, however competent he may be to discuss such topics, has little relevancy to the problem whether an individual is to be regarded as legally ' responsible.'

It is by no means easy to define clearly what we mean by ' responsibility,' even in the legal sense. The legal position would appear to be, in the words of the leading authority on criminal law already quoted : ' No act is a crime if the person who does it is at the time when it is done prevented either by defective mental power or by any disease affecting his mind (*a*) from knowing the nature and quality of his act, or (*b*) from knowing that the act is wrong, or (*c*) from controlling his own conduct, unless the absence of the power of control has been produced by his own default. But an act may be a crime if the person who does it is affected by disease, if such disease does not in fact produce upon his mind one or other of the effects above mentioned in reference to that act.' I need not in a gathering of psychologists point out the extreme difficulty of the psychological problems involved in that definition, more especially in so far as the question of control is raised. I do not believe, however, that responsibility in this sense is a practical issue at all in connection with any penal system. At least it does not arise in the form in which it is usually raised, nor at the point at which it is usually raised, in a practical consideration of the problems of punishment as affecting the individual who has infringed social laws. It is a question which we inherit from an antiquated and outworn theory of punishment. So far as real, urgent, and soluble psychological problems are involved, these arise at an entirely different point and in an entirely different connection, as we shall see presently.

It is when we emphasise the protective and particularly the reformatory aspects of punishment that the vital psychological problems emerge. So far as we base our practice in social punishments upon these two functions, it is not too much to say that our whole practice must be guided primarily by the outcome of psychological inquiry. The two functions are not in conflict. We may aim at the protection of society by the reform of the delinquent. Treatment which is successful in eliminating a particular tendency to delinquency in an individual will *ipso facto* protect the community against the repetition of this delinquency by the same individual. Of course it will not necessarily protect society against the same form of delinquency in another individual. That is why we have to consider punishment, rather than reformation pure and simple, and that is why

the silly and sickly sentimentality which regards the wrongdoer as a suffering victim rather than a criminal will always fail to appeal to anyone, no matter how soft-hearted, who regards the whole situation frankly and sanely. It is obvious also that the failure of reformatory measures must not be taken to imply the failure of society to protect itself. Other measures must be available, which are merely protective, and not at all, or only indirectly, reformatory. On the other hand, it is clear that reformation is, as a rule, the more economical way to secure protection for the community, provided there is reasonable hope of success, and so long as we restrict our attention to the individual delinquent. The reform of the delinquent is doubly a social gain. From being a minus quantity with respect to social efficiency he becomes a plus quantity. This point is especially important in the case of the juvenile delinquent.

So far as we are to aim at the protection of society by the reform of the delinquent, the punishment of the delinquent necessarily becomes an individual question, since we are concerned with the operation of motives, and that is always an individual matter. Punishment exerts its influence through disagreeableness, or the fear of disagreeableness. The question whether we can ever reform an individual by means of punishment may possibly be an arguable question. But it is only an arguable question if we interpret 'reform' to mean more than is intended when we speak of the reformatory aspect of punishment. A misdemeanour is the outcome of a certain external situation meeting with certain inner conditions in the wrongdoer, certain conditions, I mean, in his nature or mind. On a strict scientific reading of the facts we may assume that under all the circumstances of the moment the only kind of behaviour possible was the kind of behaviour that took place. That is to say, we may admit that the delinquent, being what he was, in the circumstances then present, could not have acted otherwise than he did. This may seem a very damning admission, as far as the action of the authority which punishes is concerned, if the ethical question of the moral responsibility of the criminal is to be raised as a practical issue. As I have already said, however, I do not believe that the question of responsibility in any sense, legal or ethical, arises as a practical issue at this point at all, or in this connection. What punishment does, to put the matter in its simplest terms, is so to change the inner conditions, and therefore the inner nature, that in circumstances similar to those present on the previous occasion the misdemeanour is no longer possible, a new kind of behaviour being now the necessary outcome of all the conditions present. This is a reformatory effect in a practical, if not in an academic sense.

The function normally performed by unpleasantness encountered in the activity of any living organism is to guide the activity so that unpleasantness may in future be avoided. The fear of unpleasantness again checks the immediacy of impulse, and so allows time for a new kind of behaviour to be substituted for the old kind which led to unpleasantness—the beginnings in the case of the human being, it is worth noting, of self-control. But it is only low down the scale of organic life that the phenomena are to be seen in their simplicity. As we pass up the scale the inner conditions which determine behaviour become more and more complex, and the actual results of any unpleasantness or fear become more

and more difficult to foretell. With the human being the complexity of the inner situation has become enormous. The web of impulse and motive is so intricately and so subtly interwoven that the introduction of a new impulse and motive may come to have a result wholly unforeseen and entirely different from the result intended.

Hence, however simple the general psychological theory of punishment may be, the practical difficulties of punishment in the concrete, when its aim is the reformation of the delinquent, are very formidable. One source of practical difficulty is the actual, and possibly innate, differences between individuals, which make them respond in an entirely different way to the same external situation. What is intensely disagreeable to one individual may not seriously inconvenience another, and may be positively pleasant to a third. Hence a punishment that is effective with one individual may be quite ineffective with another. There are even differences in the same individual at different times, so that a punishment effective at one time may be quite ineffective at another, even with the same individual. A second source of practical difficulty is the fact that the effect produced by punishment has a very different duration for different individuals. One extreme is illustrated by many defective delinquents.

The most important source of practical difficulty, however, is frequently our almost complete ignorance of the inner conditions which issue in any particular misdemeanour. This necessarily involves ignorance of the effect which our punishment is likely to produce. As far as the reformatory aspect of punishment is concerned, this is a very serious matter. We have to deal with an individual, and we must know the facts of that individual case. Any psychologist who has had experience of conflict cases among juvenile delinquents can easily find illustrations from his experience. The usual form of misdemeanour that occurs is stealing, and frequently irrational and apparently motiveless stealing. Thus money, jewellery, and all kinds of things may be stolen and given away, or even thrown away. Until the inner conditions are understood and the causes of the trouble removed, no kind of treatment seems to be of any avail. Or sometimes, where punishment is apparently successful in eliminating the tendency to one particular kind of misdemeanour, there is a criminal outbreak in a totally different direction, the result of the punishment itself, which more than counterbalances any apparent success.

A typical conflict case is described by Healy. This was a girl of ten, who for two years previous to coming under his notice had been addicted to stealing. She stole from her parents, from neighbours, and from school. Threats, whippings, expulsion from school were all of no avail. There was no improvement when the child was given money to spend. In all other respects her physical and mental condition appeared to be quite normal. There was no hereditary taint that could be traced. Her school-work was above the average. She liked games, and excelled in them. Apart from the stealing, in fact, she presented a complete picture of normality. Only after careful and prolonged inquiry did the real cause of the stealing come to light. This was found to be an emotional conflict which had no direct connection with stealing, but which nevertheless resulted in the stealing

as a ‘compromise formation.’ According to the girl's own account of the stealing, when she thought of certain ‘bad things,’ stealing was the only way in which she seemed to be able to escape from her thoughts. One form of misconduct was thus, as it were, substituted for another, that form which was repressed being the real source of the trouble. The futility of punishment of practically any kind in a case such as this is obvious. Punishment would in all probability only aggravate the evil. Yet when the source of the trouble was known, this case of delinquency could be, and was, dealt with successfully.

Cases of this kind tend to make one speak and think of treatment rather than punishment. It might be asked whether this is not the point of view from which all cases should be approached, not as a matter of ethics, but as a matter of practical expediency, punishment being merely a particular method of treatment. The proposition is arguable, but only so long as we confine attention to the individual delinquent, and that is only one side of the picture, as we shall see presently. Personally, I do not think the point of view will matter very much so long as we keep firmly in mind the essential fact that the action taken, whether we call it treatment or punishment, is primarily action taken by society for its own protection, the reform of the criminal being a means adopted to this end. There is undoubtedly a class of offender in whose case treatment, rather than punishment, is the appropriate notion and procedure. Other cases occur with fair frequency in which punishment as ordinarily understood is quite ineffective as regards the reform of the individual. The case of serious mental defect may be instanced. The facts are such that we find the old problems of responsibility, so far as they were practical problems at all, cropping up in a new guise, and in new surroundings. It may be possible to determine beforehand, without waiting for the event, whether punishment will be effective for reform, and if so what kind of punishment, or whether the case is one demanding treatment, and not punishment at all, and if so what kind of treatment. The problems now, however, are neither legal nor ethical problems, but purely psychological problems.

The suggestion that in some cases punishment, as ordinarily understood, may be quite ineffective leads us on to the consideration of the measures society takes, and must take, for its own protection in certain instances. The most important method of protection that society utilises is the restraint of the offender in some appropriate institution—as far as the idea of punishment is concerned, some sort of prison. The restraint or imprisonment may be merely temporary, or it may be permanent. In the first case it is clear that the reformatory aspect of punishment ought to be still kept in view, so far as the psychological situation is taken into account. If it is not, it does not require much foresight to prophesy somewhat lamentable results. In particular, if the criminal is returned to social life, not only with his tendency to the original form of misdeed unaffected, but with other anti-social tendencies developed by his prison life, or by circumstances arising out of his prison life, our only possible verdict is that society is playing the fool. On the other hand, when the restraint is permanent, while reformatory measures must not be entirely excluded as intrinsically hopeless in every case, it is clear that the whole

psychological situation and outlook are different. The prisoner will never be returned to civil life. For the protection of society he must be kept in restraint permanently. But he is a human being, and the moral sense of society will demand that he be treated as such, not merely negatively by the avoidance of inhuman conditions, but positively by the provision of such amelioration of his lot as is possible without sacrificing essential principles.

Everyone is agreed, I think, as regards these general matters. There will also be general agreement that the stigma of prison life means in itself the very serious modification of the psychological situation in the case of every individual who incurs it, so serious that no psychologist can regard short-term prison sentences with anything but dismay. It must be recognised that it is with respect to prison treatment especially that society, in protecting itself, or attempting to do so, runs the risk of making matters worse instead of better, and the gravest practical problems arise with regard to this type of punishment. Much has been done in recent years to remove acknowledged evils and defects of our prison system. Much may still be done. Nevertheless, I personally, and, I imagine, most psychologists, would look upon any further advance in the directions hitherto pursued with serious misgivings as to psychological results, until we have first attacked more fundamental problems, and reviewed our whole penal system in the light of the psychological knowledge of to-day.

Let me try to indicate where, in my opinion, the crux of the whole matter lies. I think all will agree that the very first essential is that we should have the requisite knowledge and understanding of the psychological situation with which we are faced, and the psychological effects likely to be produced by the action taken. Society has to decide whether an individual delinquent is to be punished in this way or that way, whether he cannot be reformed but must be placed under restraint for life, or can be reformed during temporary restraint by appropriate treatment, or can be reformed without undergoing prison life, and in each case what can and ought to be aimed at. No general theories concerning the causation of crime, no systems of penal philosophy, not even the best intentions in the world, can take the place of a thorough knowledge and understanding of the individual case. This is precisely where our whole penal system is at present most defective. Moreover, the defect is one that can be remedied without serious difficulty in the present state of development of modern science, medical and psychological, but no opportunity is afforded. The first and essential step towards the further reform of our penal system lies in affording this opportunity. This could be done by instituting a clinical examination, medical and psychological, of every delinquent before sentence is passed, and by taking advantage wherever possible of modern psychological knowledge. The psychological clinic is at present practically non-existent in this country. It is high time this state of matters was remedied. School and law-court both demand its institution. That is the first step. When we have taken that step, we shall be able to take further steps in penal reform, with the advantage of acting with adequate knowledge of what can be done and what we are really doing in each particular case. Until that step is taken, every other change we introduce by way of reform has a hit-or-miss character, which cannot fail

to be profoundly disturbing to any thoughtful student of social development.

But it may be objected that we are in danger of losing sight of the fact that the topic under discussion is punishment, not simply the reformation of the criminal. A few minutes ago the suggestion was made that in certain cases at least it might be more appropriate to speak of treatment than of punishment, the suggestion involving the view that delinquency ought to be looked on as the outcome of something not unlike disease. However that may be, I do not think there is any warrant for excluding either the idea or the fact of punishment, provided we look to the future, and not simply to the past, in our conception of punishment. The action taken against an individual in the form of punishment must involve some disagreeableness or deprivation, and the reason for the punishment is some past act of the individual. But its purpose is the prevention of similar acts in the future. The fact that hitherto we have been discussing the individual aspect only has tended somewhat to obscure this deterrent function, and the consideration of this function will lead us over to the discussion of the social aspect.

The deterrent function of punishment has played no inconsiderable part in the discussion of penal measures at all times. The severity of past penal systems has been largely due—almost entirely so far as it has had a rational basis at all—to the attempt to deter others from similar offences to those for which punishment is inflicted on an offender. It is unquestionably the case that many a misdeed is prevented by the fact that the individual who is tempted knows that he will inevitably pay the penalty, and it is also a well-known fact that where, through the inefficiency of the police or other cause, punishment is easily evaded, crime shows a corresponding increase. The justification of a deliberate use of punishment for deterrent purposes must rest on considerations which are other than purely psychological. Whatever justification is attempted must satisfy the moral sense of the particular society. That is, however, a side-issue so far as our present discussion is concerned. The deterrent effect of punishment as a fact is the main point that concerns the psychologist, and his business as a psychologist is to analyse and explain this fact.

It cannot be lightly assumed, however, that the deterrent effect of punishment depends merely on fear of the disagreeableness or suffering which the punishment in itself involves. The penal system is an expression, however imperfect, of the sentiments of society with respect to certain acts—sentiments of hatred in varying degrees. It is not the result of a purely intellectual review of the social results and bearing of these acts. Apart, therefore, from the punishment by law decreed and legally inflicted, the criminal act is inhibited, so far as the normal socialised individual is concerned, by this sentiment in himself and in his fellows, how developed we cannot at present stop to consider, but resting ultimately on the primitive anger evoked by injury. 'The sentence of the law,' to quote again the legal authority already quoted, 'is to the moral sentiment of the public in relation to any offence what a seal is to hot wax. It converts into a permanent final judgment what might otherwise be a transient sentiment.' Fear of the punishment as such, fear of the social

disapprobation dependent on the evoking of the moral sentiment of which the punishment is a concrete and tangible embodiment, recoil from the act because of the existence in the individual who is tempted of the moral sentiment in question in however feeble, attenuated, and fragmentary a form—all these are motives holding back an individual member of society from wrongdoing. The legal punishment exercises its deterrent influence because it, as it were, embodies and presents all of them in unmistakable and arresting fashion. The relative force of the different motives will vary with individuals. But until we can rely on the last of these motives being of itself sufficiently powerful to restrain every individual member of society from the breach of social laws—which would seem to involve a radical change both in the existing social structure and in human nature—the social necessity of some kind of penal system, in the strict sense, must remain.

Arguing on the basis of the deterrent influence of punishment, several writers have defended punishments which can only be described as vindictive. This has been due in part to the belief that the deterrent effect depended solely on fear, and in part to inability to distinguish between hatred of an offence and hatred of the offender. After the sound and generally acceptable statement of the relation between penal law and the moral sentiments of the community, just quoted, the same legal authority goes on to say: 'The criminal law thus proceeds upon the principle that it is morally right to hate criminals, and it confirms and justifies that sentiment by inflicting upon criminals punishments which express it.' This is a frank enough expression of the vindictive theory of punishment. We are here concerned neither with the ethics nor with the religion of the view thus expressed. It is certain that, psychologically, hatred of a sin need not involve hatred of the sinner. It is also certain that the writer in this passage is speaking of the emotions of anger and revenge, and not of any moral sentiment at all.

I do not wish, however, to develop that line of thought at present. Enough has already been said about vindictive punishment. I would rather in conclusion revert to the varying motives upon which the deterrent influence of punishment depends. Two points in particular demand notice. In the first place we cannot assume that penal law and moral sentiment will always be in harmony, and so reinforce one another. There may, in fact, be acute conflict between the two, as far as a considerable minority of the members of a community are concerned. In certain cases also they may be, so to speak, indifferent to one another. In either case the psychological situation is very radically modified, and the problems of punishment may in practice become very difficult.

In the second place the influence of the different motives may, as we have seen, vary with the individual. If that be so, two consequences would appear to follow. On the one hand—and this refers more particularly to the adult criminal—our penal system must be such as to appeal with sufficient cogency to all the motives, as far as the criminally disposed individual is concerned. On the other hand—and now we have in mind chiefly the juvenile delinquent—it is of capital importance that we should recognise as early as possible in their criminal career those individuals who, either by nature or circumstances, or both, are tending towards abnor-

mality in their reactions to social claims and social penalties. This brings us back to the crux of the whole situation. Means must be provided by which a knowledge of the individual case may be made available, before the decision is taken as to how any offender is to be treated. The temperamentally defective individual may be born, the habitual criminal is largely made. It ought at least to be possible to prevent the making of criminals. Again the glaring defect of our penal system stands revealed. No provision whatever is made for the diagnosis of incipient criminality. It is not merely a case of locking the door after the horse is stolen; it is a case of providing neither lock nor door.

SECTION K.—BOTANY.

1860—1894—1926.

ADDRESS BY

PROFESSOR F. O. BOWER, Sc.D., D.Sc., LL.D., F.R.S.,

PRESIDENT OF THE SECTION.

'*The future of Biology lies not in generalisation but in closer and closer analysis.*'—Bateson (Birkbeck Lecture, 1924).

Death sudden and wholly unforeseen has stepped between this Section and the President of its choice. Professor Bateson had presided over the whole Association at its meeting in Australia, and partly on that account he had been specially selected for the chair of this Section in Oxford. From him we might have expected a broad outlook upon biological science. His address would have been instinct with wide experience in both of the branches of living things, the interests of which interweave in enthralling and often most perplexing ways. We should have heard a fearless statement of his mature views. Something constructive would certainly have justified the congratulations with which some of us had already welcomed his nomination. A great figure has been taken from the arena of biological science. A career still full of the promise of further achievement has closed prematurely.

This is not the time or the place for any comprehensive obituary of Bateson; nor would I divert your attention from those already before you, written by more competent hands. I will only allude briefly to four leading events in his scientific career. He felt in early life the lack of facts bearing on variation, and sought to extend their area in his great work 'Materials for the Study of Variation,' published in 1894. This was the year when the Association last met in Oxford. I do not remember that its contents came into the discussions in Section D, though the book centred upon the vital question of continuity and discontinuity. The second event was the publication in 1902 of 'Mendel's Principles of Heredity,' in which, though essentially a controversial statement, Bateson perceived latent in the rediscovered writings an expanding vista of advance. 'Each conception of life (he says) in which heredity bears a part must change before the coming rush of facts.' In a third stage of his work Bateson expanded this theme into a fuller statement under the same title, and it was published in 1909. Passing from this period of high hopes to the fourth phase of 1924, we see in his Address at the Birkbeck Centenary a chastened attitude. He there remarks: 'We must frankly admit that modern discoveries have given little aid with the problem of adaptation,' and that, much as Mendelian analysis has done, 'it has not given us the origin of species.' But that analysis having 'led to the discovery of transferable characters, we now know upon what to

concentrate. . . . Henceforth the study of evolution is in the hands of the cytologist acting in conjunction with the experimental breeder. Every appeal (he says) must ultimately be to the mechanics of cell-division. The cell is a vortex of chemical and molecular change. . . . The study of these vortices is biology, and the place at which we must look for our answer is cell-division.' I would ask you to mark that last word. It is cell-division, not nuclear division ; and earlier in his address we find the pregnant sentences : 'As to what the rest of the cell is doing, apart from the chromosomes, we know little. Perhaps the true specific characters belong to the cytoplasm, but these are only idle speculations.' Such extracts from Bateson's latest public pronouncement may suggest to you what the Section has lost by his death. They show the mind still elastic and perceptive : still both constructive and critical.

Any address that follows such a tragedy of disappointment as the Section has suffered can only fall short of what we had hoped to hear. Instead of attempting to fill the broad biological rôle that naturally fell to Bateson, I propose to centre my remarks upon three dates when the Association has met in Oxford, viz. 1860, 1894, and 1926. It happens that these dates mark approximately periods of transition in the progress of biological science, and particularly in Botany.

1860.

I need not remind you of the fact that the meeting in Oxford of 1860, the year after the publication of the 'Origin of Species,' witnessed the clash between the new view and the opposition it was certain to arouse. The story has been often told of the aggressive attack and the crushing retort. But it is not sufficiently recognised that, though Huxley bore the first brunt of the fight, a large part in the contest was taken by Hooker. The meeting closed after he had spoken, and in his own words he was 'congratulated and thanked by the blackest coats and the whitest stocks in Oxford.'

Two generations have passed since the Oxford meeting of 1860 : and still the 'Origin of Species' holds its place as a great philosophical pronouncement. As the methods of research passed into greater detail, the area of fact has been extended through the labours of an ever-growing army of inquirers, and naturally divergences of view have arisen. Some authors appear to demand that for all time the 'Origin' must cover every new aspect of biological inquiry, or else the whole theory crumbles. That is to demand a prophetic vision for its author. We need not for the moment follow these or other criticisms, but rather recognise that the theory rested essentially on facts of heritable variation, without defining their magnitude, limitations, or origin ; and that it explained a means of their summation so as to produce progressive morphological results. As an index of current opinion on the validity of Darwin's theory as a whole, I would draw your attention to three British works on evolution, all published within the last two years. In 1924 Dr. Scott concludes his volume on 'Extinct Plants and Problems of Evolution' with the judicious sentence : 'I may venture . . . to maintain that a consideration of all the evidence . . . is on the whole favourable to the old, truly Darwinian conception of an orderly and gradual evolution without sudden and inexplicable

leaps, an evolution in harmony with the uniformitarian principles established by Lyell.' But he remarks that he does not favour any exaggerated ideas such as the so-called 'omnipotence of natural selection.'

In the present year Professor Graham Kerr, in his volume on 'Evolution,' also adopts a distinctly Darwinian position, but with greater stress laid upon the potency of natural selection; this might be expected from one who spent some of his most impressionable years in the wild surroundings of the Gran Chaco. He speaks from experience of the effect of selection as being 'in actual fact enormous,' and he holds that the attempts that have been made to minimise its importance are to a great extent fallacious. He sees in the recognition of Mendelian inheritance that the natural-selection theory has been greatly fortified since Darwin's day. Variability, upon which the theory depends, he regards as an expression of that instability which constitutes one of the inherent and most characteristic features of living substance, and he states that such variation has to be accepted as a basic fact. He further regards as an added strength to the Darwinian theory 'the recognition that a particular variation is the outward expression of a *tendency* to vary in that particular direction, and that as a consequence the selection of variations in a particular direction involves a necessary intensifying of the tendency towards that particular variation, and in turn the encouragement of evolutionary progress along a definite directed line.' These expressions are in general accord with the doctrine of Weismann that acquired characters, or, as Graham Kerr terms them, 'impressed' characters, are not themselves inherited. It is not for a botanist to interfere with the arguments of zoologists on this question, as applied in their own science. There are, however, zoologists who strongly maintain their belief in such inheritance, a position upheld by Professor MacBride in the volume on 'Evolution' published last year by Messrs. Blackie, which is the third of the works above mentioned.

In that same volume I took the opportunity of stating that the question of the origin of heritable characters, or mutations as they are called, is still quite an open one for plants. But it was maintained that a wide latitude of time is a real factor in the problem. This was already recognised by Hofmeister, who on the last page of his 'Allgemeine Morphologie' said: 'It appears to me probable that only gradually, in the course of many years' development, the influential effects on outer form appeared and became hereditary.' Thus Hofmeister contemplated a slow inheritance of acquired or impressed characters in plants. To anyone who notes how directly susceptible individual plants are to external conditions, and how greatly these affect their individual form, it would seem improbable that there should be any sharp line of demarcation between the individual and the racial life, or that what affects every individual plant so profoundly should never affect the race. In my essay in Messrs. Blackie's volume on 'Evolution' I advanced comparative evidence, which commends itself to my own mind as a morphologist, indicating that the boundary between fluctuating variations and heritable mutations is not absolute: in fact that in plants, given latitude of time, variations related causally with external circumstance, and not merely initiated at random, are liable to be transmitted to the offspring. There is no need to repeat the

argument here, for it was submitted to the Section at Southampton. It may be remarked that this is in direct opposition to the doctrine which Weismann laid down with special reference to the animal kingdom. But what may be applicable for one kingdom of living things does not necessarily apply for the other. The evolution of animals and plants has certainly been homoplastic in all its later stages. Our minds should be perfectly free to follow the facts of our own science to their legitimate conclusions. These indicate to me that heritable variations in plants have been promoted or actually determined in their direction, or their number, or their quality, in some way by external conditions. But these need not necessarily have worked within restricted time-limits of present experiment; for the wide latitude of geological time has been available for evolution to proceed. Hence negative results of the experiments of a few years need not be held as overruling the conclusions drawn from comparison of nearly allied forms.[1]

Before we leave this historical aspect of evolution a moral may be drawn from the lives of its four protagonists of 1860. Darwin, Wallace, Hooker, and Huxley were all equipped for the battle from the armoury of personal experience in the great world. The theory of evolution was born and bred of foreign travel, and upon foreign travel quite as much as upon quiet work at home its future still depends. We should not for a moment minimise the great developments of laboratory study and of breeding experiment in recent years that bear upon its progress. But it is not thence alone that the fullest achievement can be anticipated. The cytologist and the breeder, just as much as the abstract theorist, should know Nature face to face, not merely through a glass darkly. To those who believe in the close relation between environment and variation, which is to me the very core of evolution, this seems essential to any well-balanced view. The open forest, the sea-coast, steppe, and mountain-side should be regarded as the natural complement to the laboratory and the breeding-station. No one, morphologist or physiologist, should hold himself equipped for research or fully qualified to teach unless he have at least some experience of travel through wild Nature. This can best be acquired in the tropics. But what do we find?

In 1886 a committee of this Association was appointed to assist the visits of botanists to Ceylon for study. Several well-known botanists availed themselves of its aid; but after a few years the scheme flickered out through inanition. In 1909 I visited the Cinchona Station in Jamaica, and again a scheme for continued use of the station by British botanists was initiated; but it has since died out for want of consistent support. Why did these efforts fail? We may set these failures down to undervaluation of the importance of foreign, and particularly of tropical, study; and the lack of full perception that open Nature is the greatest laboratory of all. Our future Botany seems in danger of becoming myopic by reason of study being concentrated at too short focus. To correct this, young aspirants should travel early, as free-lances, hazarding the fortune of the wild, as Darwin and his fellows did.

[1] Gates, in his volume on the 'Mutation Factor in Evolution' (1915), draws to a close with words that may well be quoted here. 'It would appear (he says) that something within the organism is responsible for such unswerving progress in a given direction as appears to be repeated over and over again in the palæontological record.'

Homoplasy.

I have already alluded to the tempestuous meeting of 1860 in Oxford. Shortly after it an undergraduate came up to Christ Church who, before he was of standing to take his M.A. degree, had himself made a real contribution to the philosophy of evolution. It was Ray Lankester, who in 1870 published a short paper 'On the use of the term Homology in Modern Zoology, and the distinction between Homogenetic and Homoplastic Agreements.'[2] Its author was only twenty-three years of age, and its date barely a decade after the publication of the 'Origin.' This short paper went far to clear up the vague ideas surrounding the term 'homology' in the minds of early evolutionists. Lankester introduced the idea of 'homogeny,' substituting in a more strict sense the word 'homogen' for 'homologue.' He also suggested, to avoid confusion, the use of another new term, viz. 'homoplasy.' He defined homogeny as simply the inheritance of a common part, while homoplasy depends upon the common action of evoking causes or of a moulding environment upon homogeneous parts, *or* upon parts which for other reasons offer a likeness of material to begin with.

This definition was at once adopted in the morphological study of animals, but Lankester did not himself apply it at the time to the morphology of plants. In point of fact the conception of homoplasy and the use of this clarifying term made its way but slowly into botanical literature. There is reason to believe that we are as yet only beginning to recognise in the evolution of the plastic plant-body how far-reaching has been the influence of homoplasy, not only upon external form, but also in the internal evolution of tissues. As to external form, a wide recognition of the results of homoplasy is now generally accepted for land-living plants, and in particular in respect of the origin of foliar appendages; for instance, the leaves in Bryophytes and Vascular Plants are held as homoplastic, not as homogenetic; similarly with the leaves of Bryophytes, and possibly also of Pteridophytes, *inter se*. On the other hand, we may find among the larger Brown Algæ indications of the differentiation of a supporting organ and lateral appendages from a common branch-system, that can only have been homoplastic with an origin of like parts in certain Red Algæ. Such conclusions, drawn from the Algæ themselves as well as from the Archegoniatæ, have the natural effect of raising distrust of wide comparisons between any seaweed and any land-plant in respect of foliar differentiation. Comparisons of this nature cannot be held acceptable as mere guesses, by loose reference between one class and another. They would have to be based on the recognition of compact sequences within reasonably close circles of affinity before they could carry conviction.

Similarly in the morphology of the internal tissue-tracts, we are already familiar with certain examples of homoplasy; for instance, that of secondary thickening. No one would now hold, with the school of Brongniart, that all plants with cambial activity are akin. But it is only in later years that we have come to realise the far-reaching results of homoplasy in the region of primary vascular morphology. Medullation,

[2] *Ann. and Mag. of Nat. Hist.*, vol. vi, p. 34.

solenostely, polycycly, and dictyostely have all arisen in more than one phyletic sequence, while the fluted form of the stele, or of the xylem-tract that it contains (which gives a stellate transverse section), is now recognised as a conformation meeting the demands that follow from increasing size, rather than as an indication of community of racial origin. These are examples of the effect of internal homoplasy. We are only now beginning to realise how far-reaching have been its results in plants as we see them. On the other hand, such realisation when well assured cannot fail to react upon our estimates of affinity of the organisms in which homoplasy appears. It may be going too far to trace all such results as consequences of the meeting of 1860; but the initiative was certainly given by Lankester in the years that followed.

1894.

Passing from the stormy period of 1860, when the whole outlook of biological science was being transformed by the advent of evolution, to 1894, we see that the atmosphere had cleared. One result was that the evidence of descent tended to become too definite in the minds of some enthusiasts, and there was even a disposition to argue deductively from the accepted position, a tendency that is much too prevalent to-day. I feel bound to refer critically to my own contribution to that meeting, which was the statement of a Theory of the Strobilus. Thirty years have materially extended the field of established fact. Though certain parts of that theory relating to sterilisation may still hold, in view of new and material facts any close comparison between a vascular strobilus as a whole and a bryophytic sporogonial head must fall. In particular, the suggestions of progressive septation and eruption of appendicular organs cannot now be upheld as accounting for the origin of a compact strobilus. The theory was stated tentatively, as a working hypothesis, and time has shown that the hypothesis does not accord with facts now known.

The outstanding feature of the Oxford meeting of 1894 was Strasburger's generalisation on the Periodic Reduction of Chromosomes. This shed a new light on the vexed question of alternation which, based on the brilliant results of Hofmeister, by this time held the field not only as an objective fact but as an evolutionary problem. The effect of Strasburger's communication was to establish the chromosome-cycle as general for plants that show sexuality. It provoked comparison with a similar cycle in animals. The recognition of both cycles took its origin in the discovery by van Beneden in 1883 that in sexual fusion the number of chromosomes is the same in both of the conjugating nuclei. Later observers have confirmed this in a multitude of instances, and disclosed the correlative reduction, or meiosis. The existence of a nuclear cycle alike in animals and in plants cannot, however, be held as establishing any homogenetic unity of the two kingdoms. Comparison of the simpler forms of each indicates that the divergence of the kingdoms, if they ever had a common origin, was very early indeed, and probably antedated sexuality in either. Such similarities as they show in propagative detail, and particularly in the nuclear cycle, would be homoplastic, not homogenetic. If this be so for the two kingdoms of living things, may it not be equally true for the several phyla of plants that show sexuality; for we are not justified in assuming that sexuality arose but once in plants?

Historically this generalisation of Strasburger fell like a bomb-shell into the midst of the old controversy between the rival theories of alternation, styled in the words of Celakovsky 'homologous' and 'antithetic.' But it must be remembered that at the moment there was no complete demonstration of a cytological alternation in any one Alga, though the facts soon followed for *Fucus* [Strasburger (1897), and Farmer and Williams (1898)]; and for *Dictyota* (Lloyd-Williams, 1897–8). We need not recite again the arguments *pro* and *con* of that old discussion. It soon lost its intensity in face of the obvious deficiency of crucial facts, which alone could lead to some final conclusion. Loose comparisons between organisms not closely allied are but the long-range artillery of morphology. Comparisons between organisms closely related are its small-arms. The discussions of the 'nineties of last century on alternation were all engagements at long range, which could not be decisive without the use of close comparison. As the necessary facts were not then in our hands, those premature engagements might be held as drawn; and it was open to both parties still to entertain their own opinions. Meanwhile it may interest us as spectators to note the relation that exists between homoplasy as defined by Lankester in 1870, and those intimate questions that arise from Strasburger's paper to this Section in 1894. The cytological facts acquired since the latter date tend to confirm the normal constancy of a nuclear cycle. Their effect has been to accentuate more than before the inconstancy of the somatic developments related to it. Like the fabulous genie let loose from its bottle, the conception of a nuclear cycle in plants that show sexuality, disclosed in 1894 by Strasburger, dominates ever more and more the morphological field.

Before discussing the relation of somatic development to that cycle, it will be well to revise the terminology. The word 'homologous' has a double significance, as shown by Lankester. If it be used to include examples of 'homoplasy' the whole field is open for what has been styled antithetic alternation, in which the two generations were presumed to be homoplastic. If in the sense of 'homogeny,' then it would be necessary to prove the relation of the somata throughout descent to the nuclear cycle. On the other hand, the term 'antithetic,' while it accentuates the difference between the two somatic phases, is not explicit, in that it does not describe the method believed to have been involved in their origin. It would be well to drop these old terms, which are neither exact nor explicit, and to support a more general use of the words '*interpolation theory*' in place of 'antithetic' and '*transformation theory*' in place of 'homologous.' These words accord better with current views, and are explicit.

1926.

From the time that the periodic reduction of chromosomes was recognised as general in organisms showing sexuality, the nuclear cycle has formed a natural foundation for the comparison of the life-histories of plants. The normal cycle may be figured to the mind as a closed circular thread with two knots upon it, syngamy and reduction. Between those knots beads may be strung, one, or more than one, or none. These represent somatic developments, which are normally diploid between syngamy and reduction, haploid between reduction and a fresh act of syngamy. They

follow in alternate succession in any normal cycle, but either may be repeated indefinitely by vegetative propagation. Certain questions arise with regard to the evolution of these somata as we see them. The first is, how far are the diploid and haploid somata of the same cycle comparable one with another ? The reply will turn upon the constancy of the events of syngamy and reduction throughout descent. If they were constant, then it appears a necessary consequence that the alternating diploid and haploid somata must have been distinct throughout their history ; and any similarity which they may show, as in *Dictyota* or *Polysiphonia*, would be homoplastic. It would, indeed, appear natural that they should be alike in Algæ, since they are parts of the same organic life and live under identical circumstances. It has, however, been suggested that reduction may not be a fixed but a movable event in the individual life : liable to be deferred or carried over to a later phase, in which case a diploid generation might arise by transformation from an already existent haploid phase. The monospores of the Nemalionales have been cited as possibly convertible in other Red Seaweeds into tetraspores, by some sudden deferring of the act of reduction. I am not aware that this has been advanced by close comparison beyond the position of tentative suggestion, though the existence of a diploid gametophyte and of a haploid sporophyte in certain abnormal ferns would indicate the possibility of the suggestion being true. Pending the advance of a closely reasoned argument it is best to keep an open mind.[3] Meanwhile the weight of facts hitherto known from plants at large may be held to support the stability of the events of syngamy and reduction during normal descent. The two generations of the same life-cycle would, in the absence of a carry-over of reduction, be homoplastic, not homogenetic.

It is, however, round a second question that divergent views as to alternation chiefly centre. How far are the diploid and haploid somata in the cycles of different types of organism comparable one with another ? This is, in fact, the old problem of Pringsheim and Celakovsky. It applies to all plants where somata alternate, but a special interest attaches to the case of Land-living plants ; in particular, we shall trace the origin of the dominant sporophyte of a Land Flora, and inquire whether it originated by *transformation* of diploid developments such as are seen in certain Algæ, or by formation *de novo* through *interpolation* ? A clear statement of the former hypothetical alternative was made by Scott in 1911, viz. 'that the Fern with its stem and leaves corresponds to the Seaweed in which stem and leaf are not differentiated, the whole plant being a thallus.' 'On this theory the sexual prothallus and the asexual plant are both alike derived from a thallus, and may once have been perfectly similar to each other.' In alluding to leafy Liverworts and some of the higher Seaweeds as illustrations, he then remarked that 'these are only analogies, it is

[3] Even if such a carry-over of reduction were proved to occur in certain Algæ, I do not see that this would disprove interpolation in other organisms. We have been too apt to assume that all alternation arose in the same way—*either* by interpolation *or* by transformation. Among the infinite possibilities of Organic Nature I see little justification for assuming this. The evolutionary problem has been to impose the amplification of a vegetative system upon a nuclear cycle. I see no reason to exclude its solution in a multiplicity of ways. (*Cf.* J. Buder, 'Zur Frage des Generationswechsels im Pflanzenreiche,' *Ber. a. d. Bot. Gesellsch.*, 1916, p. 559.)

true.' But after reference to the fossil evidence, as it then was, he concluded that it is more probable that the higher Cryptogams came direct from plants of the nature of Algæ than from Bryophyta or any plants at all like them; he added, however, that 'this view is pure hypothesis.' It must, of course, be remembered that these quotations from Dr. Scott's 'Evolution of Plants' (p. 225) were of pre-Rhynie date. A luminous statement of his later views was contained in his address to Section K in Edinburgh in 1921, which will be in the memory of you all.

Church, in his vivacious essay on 'Thalassiophyta' (1919), went much further than this guarded and scientific statement by Scott of 1911. By 'deduction from types still existent in the sea' he assumes 'Algæ of the transmigration' as a bridge between the vegetation of land and sea. His transmigrant Algæ 'appear, in fact, to have been more highly organised than any single algal type at present known to exist in the sea,' and 'to have combined the best features, as factors of the highest grade of progression, of the known great conventional series of marine phytobenthon, and yet to have belonged to none of them.' He boldly fills the gap that puzzles us all by hypothetical organisms that no one has seen, and which he expressly tells us we shall never see (*l.c.*, p. 88). If the discussions of the 'nineties were inconclusive engagements at long range, what is this? It is certainly not that closer analysis advocated by Bateson.

An alternative to such an effort of imagination may be found in the examination of organisms that really exist, or are known to have existed, illuminated by the conception of homoplasy, or, as it is often called, parallel-development. The comparisons should be based upon the recurrent fact of the chromosome-cycle, since this underlies the ontogeny of all plants that show sexuality. Somatic development in sexually produced organisms is seen to be in some measure independent of the successive events in the chromosome-cycle. The somata may be unicellular, existing only as potential gamete or zygote respectively; they need not necessarily be alike in themselves, nor need they appear at the same points in the cycle. For instance, it is found that the pennate Diatoms have diploid vegetative cells, while in the centric Diatoms they are haploid, this latter state being shared by the vegetative cells of the Desmideæ and Zygnemeæ. That a soma should appear at the same point in the cycle of two or more organisms does not necessarily prove that they have had the same phyletic history. The full proof that they did can only follow from the observation of sequences of close relationship, which should indicate the successive steps to have been the same if a true homogeny exists. We are, in fact, thrown back upon close comparative observation for tracing truly homogenetic sequences of somatic development, rather than upon the mere position of a given soma in the cycle, or the recognition of its diploid or haploid state. Until such evidence is available it will be best to hold it as possible that the origin of any somata compared has been homoplastic.

Some such view as this was clearly in the mind of Professor Oltmanns in 1923 (*Morph. und Biol. der Algen*, vol. iii, p. 143). Speaking with the fullest knowledge of the cytologically distinct alternation as it appears in the Algæ, he says: 'When we affirm that an alternation of a gametophyte and a sporophyte is seen in the more highly developed Algæ, that is not

the equivalent of saying that all the forms cited betray an affinity to the Archegoniatæ. Just as sexuality may be held to have arisen repeatedly and independently in various groups of the lower organisms, so may the various higher families have carried out independently the establishment of two generations. Where a second generation is present we may assume that it was independently interpolated, and has developed from small beginnings such as we see in *Œdogonium* or *Sphæroplea*, &c.' If this be admitted for various families of the Algæ, it may be contemplated the more readily for the Archegoniatæ, which are more distinct in their characters from the Algæ than these are among themselves.

No one has yet made out a closely reasoned case for the descent of the Archegoniatæ from the Green, the Brown, or the Red Algæ. The old view that they originated from the Green Algæ has never recovered from the blow delivered by Dr. Allen, when he showed that the reduction in *Coleochæte* takes place in the first divisions of the zygote, and that the presumed primitive sporophyte is really haploid, and not cytologically a sporophyte at all. It is a perfectly tenable position to hold that the Archegoniatæ sprang directly from none of these groups, as we know them. In the absence of definite comparative evidence the field appears to be open to an origin of alternation in the Archegoniatæ by interpolation of a sporophyte *de novo*, developed not in water but in relation to a land-habit. Against such an origin of a sporophyte there is in some minds a strange, and to me an inexplicable, preconception. Many years ago Professor Von Goebel drew attention to a curious leaning among morphologists towards reduction-series. It appears as a prevalent psychological phenomenon that men are more prone to admit down-grade sequences than those that are up-grade. But it is clear that in evolution at large there must have been a credit-balance of upward development as a whole, otherwise no multicellular organisms could exist at all. Each morphologist no doubt strikes his own financial balance at the end of the year, and notes justly whether or not his credits meet his debits. Why should he not carry forward the same accurate balance of amplification against reduction into his morphology? But we find him cheerfully accepting evidence of the practical elimination of the gametophyte in Seed-plants, and contemplating a similar elimination in the Brown Seaweeds, thus making drafts upon his morphological account. When, however, an origin by interpolation of the sporophyte is suggested to him, he regards this morphological asset with something more than suspicion. He will overdraw his morphological balance more willingly than he will pay in assets to his morphological credit.

Here it may be well to consider what rational explanation is now possible for the origin of a diploid generation. The old biological idea that the alternation arose in relation to amphibious life will not suffice, since alternation is seen to exist in fully aquatic Algæ. Nevertheless, the amphibial life may have been one of the circumstances that have modified the development, and guided it into the special channel seen in Archegoniate Plants. Svedelius, however, suggests a more general reason for the somatic development of a diploid sporophyte which deserves the most careful attention ('Einige Bemerkungen ueber Generationswechsel und Reduktionstheilung,' 1921). Instead of laying weight upon

meiosis as reconstituting the daughter-nuclei, he suggests that the greatest importance of the reduction-division lies rather in its making new combinations of chromosomes possible. He points to the difference between only one reduction in each cycle, as in the simplest organisms, and many, as in those that have achieved a higher development; and he concludes that the origin of a large diploid sporophyte is thus an advantageous biological organisation, since it secures many reduction-divisions, and consequently numerous new combinations. This hypothesis has the advantage of giving a general explanation of the origin of a diploid sporophyte, independently of any special circumstances of life under which it came into being.

Devonian Fossils and a Land Flora.

We may here leave aside any detailed study of alternation in the Thallophytes, though it is full of interest, and the investigation of it rich in promise; particularly that of the Brown Seaweeds, as last year's proceedings of the Section have shown. This year we may concentrate on the Land Flora, and inquire how recent discoveries may have affected our outlook on it. Notwithstanding that the years since 1894 have been marked by discoveries of the first rank, I see no reason to alter my belief in an interpolated sporophyte in the Archegoniatæ, except in respect of the primary causality; nor do I relinquish the view that the two generations are homoplastic and not homogenetic. Indeed, the new evidence appears to me to strengthen rather than to oppose the position previously stated. I see no need materially to modify the biological reasoning which I offered in 1890 in explanation of the formal difference in Land-plants between the alternating generations, nor the recognition of the stabilising influence of the amphibious life upon them. But the new discoveries have altered the aspect in certain particulars, and in nothing more than in the relations of the Bryophyta to the rest.

The most impressive event of recent times in the sphere of morphology has certainly been the recognition and constitution of a new class of vascular plants. The disclosure of the fossils of the Rhynie Chert, of early Devonian age, is not only notable as introducing in unusual detail a type of vegetation barely hinted at before, but also because those early land-plants present material of the highest importance for comparison. The new class of the Psilophytales was founded to receive them, together with the old Devonian fossil *Psilophyton*, and some others; while their relation to the living Psilotaceæ is recognised. These rootless plants together present a new facet upon the problem as to the origin of members in vascular plants, though they do not wholly resolve it. Apart, however, from such conclusions as the new facts may suggest, they introduce a tonic effect into morphology. Something positive is actually seen, and of very early existence, as a set-off against reasoning from data so often isolated and insufficient, or even purely imaginary. For a balanced statement on land-vegetation viewed in the light of the newly acquired facts one cannot do better than refer to Chapter VI of Dr. Scott's book on 'Extinct Plants and Problems of Evolution,' 1924. Discussing the relation of the Bryophytes to other Archegoniatæ, he remarks how Kidston and Lang had pointed out that the three phyla, Pteridophyta, Bryophyta,

and Algæ, are undoubtedly brought nearer together by the Rhynie discoveries; and I may be pardoned for re-quoting from him a passage of my own (*l.c.*, p. 205): 'Long ago it was remarked that the widest gap in the sequence of plants was that between the Bryophytes and the Pteridophytes. It is within this gap that the newly discovered fossils take their natural place, acting as synthetic links, and drawing together more closely the whole sequence of land-living, sporangium-bearing plants.' Under the influence of these and other late discoveries the Bryophyta are coming into their own. Not only has the problematical *Sporogonites* been described by Halle from the Devonian rocks, but undoubted Liverworts of the Carboniferous Period have been disclosed by the refined methods of Walton. These events coincide with the advent of the Psilophytales, the most sporogonium-like of all vascular sporophytes. It seems there may be a natural place for *Anthoceros* at last, as Campbell tells us.

The effect of the establishment of the Rhyniaceous type on the comparison of the parts of the sporophyte is important; in particular the question of the origin of the root and leaf may be canvassed afresh. We see a class of early rootless, land-living sporophytes, sharing this feature with the Psilotales, and we may reasonably hold them to represent a primitive type. On the other hand, we see in all Pteridophyte embryos which have a suspensor that the root, often late in appearance, is a lateral appendage on the embryonic spindle. Moreover, the root arises as an exogenous growth in *Phylloglossum*, and in certain species of *Lycopodium*, as do also the enigmatical rhizophores of *Selaginella*. Provisionally, then, we may conclude that the root is a late addition to the plant-body in descent, and that it was in the first instance some form of exogenous branch at the base of the primitive sporophyte, such as is seen in the Psilotaceæ and in *Asteroxylon*.

Much greater interest and more consecutive reasoning centres on the question of the foliar developments of vascular sporophytes. Studies on 'Leaf-Architecture' and passages dealing with that subject in my book on Ferns, vol. i, have shown that, by inductive comparison based on an analysis of plants now living, we may arrive at a theoretical origin of leaves of the Fern-type from a dichotomously branching system; and already in 1884, long before the discovery of the Psilophytales, this conception had been tentatively extended to include the axis as well, though the material facts such as we now possess were not then in evidence. It was also concluded from comparison of living plants that the sporangia were originally distal on the branches. Thus the Psilophytales supplied in actual fact a sub-aerial type already contemplated as a result of inductive argument. If this origin of a Fern-shoot by sympodial development from a dichotomous branch system, such as that of the Rhynie fossils, be true, there would be no need to draw upon supposititious 'Algæ of the transmigration' to explain the origin of leaves of the Fern-type, for sub-aerial plants would be seen to have originated such leaves for themselves. Any similarities between Algæ and Ferns in respect of foliar appendages would appear only as interesting facts of homoplasy.

This does not, however, exhaust the question of foliar origin. Such plants as *Thursophyton* and *Asteroxylon*, as well as the living Psilotaceæ, present features which suggest a second type of foliar appendage. Lignier

has long ago designated these as 'phylloides,' while his 'cauloides' correspond to the leaves of ferns. I do not propose here to discuss this difficult question. The present purpose is fully served by showing that induction from the facts of land-living plants alone will now give a reasonable history of the origin of leaves of the Filicinean type, without any need to refer to some transmigrant Alga to explain it. Why should we assume any limit to the capacity of Organic Nature to originate new members? Or to do this in more than one way, and in more than one phyletic line? At the back of the theory of Transmigration is the assumption that she cannot, or probably would not, do this. But a wide comparison of things now living before our eyes, or that have lived, shows that she can, and that she has done it repeatedly.

Palæobotanical discovery has been greatly advanced within the period under review. The features of the vegetation of Mesozoic time are becoming clearer than ever before under the hands of Professor Seward. The Carboniferous Flora has been richly presented to us by Williamson, Scott, Oliver, and Kidston in Britain, and by Continental workers such as Renault, Zeiller, Bertrand, Nathorst, and Solms-Laubach. We are now able to substitute something positive in place of vague surmisings. Not only do the new facts illuminate our knowledge of plants now living, but they also apply a check upon theories as to their origin. Latterly a vision is becoming ever more and more real of a Devonian flora, revealed by Kidston and Lang at home, and by other workers in Scandinavia, in Germany, and in America. Given more extended collecting, an improving technique, and the fortune of finding more material as well preserved as that at Rhynie, who knows but what the coming decades may see the land of the Devonian period clothed before our eyes by a flora no less stimulating and even more suggestive than that of the coal? But though Devonian lands are the earliest yet known to have supported a sub-aerial flora, the highly advanced structure of such a fossil as *Palæopitys Milleri* suggests that we are still far from visualising the actual beginnings of Land Vegetation. Moreover, the mixture in the Rhynie Chert of Algal types with vascular land-plants presents at the moment a problem as perplexing as it is ecologically strange. It is always difficult to estimate justly the times in which we live; but we may well believe that the future historian of botany will note the present period as one specially marked by successful study of the floras of past ages, and by the increasing cogency of their comparison with the vegetation of the present day.

The 'Annals of Botany' as an Historical Document.

Perhaps too much of your time has been claimed for morphological questions, which are closely related to the dates of the three meetings of the Association here in Oxford. The brief space that remains may be devoted to a more general survey of the period which these dates cover. In this we could not do better than to take as an index the pages of the 'Annals of Botany,' for the existence of which we owe a deep debt to the Oxford Press. In 1860 there was no organised laboratory teaching of Botany in any University in Britain; and as yet there was no journal of the nature of the 'Annals.' But the revival of close observational study in Botany under Huxley and Thiselton Dyer at South Kensington in the early

'seventies, recorded last year by various writers in the 'New Phytologist,' was beginning to take effect in 1881, when the British Association met in York. There the outstanding feature was the address of Hooker on Geographical Distribution. This and the papers by Bayley Balfour on Socotra and by Baker on Madagascar were all that really mattered botanically, and almost all the contributions were systematic or regional in subject. The revival of the laboratories had not yet fructified. At this time all the work that was done in laboratories was called 'physiology,' as distinct from systematic botany, which was conducted on dry specimens in the herbarium. In 1887, six years after the York meeting, the 'Annals of Botany' was founded through the activity of Sir Isaac Bayley Balfour, and a small committee of guarantors whose personal security induced the Clarendon Press to make the venture. From the start that journal has paid its way. The forty stately volumes form a record, between the pages of which you may read the history of botanical progress in Britain, and in some degree also in the United States, for American botanists have always been with us in its pages. In the first issues of the 'Annals,' morphology and systematic botany preponderated, and from the proceedings of the meeting of the Association in Oxford in 1894 we see that this was still so. That meeting witnessed a crisis in the affairs of botany in Britain. A newly established Section I of Physiology assumed that the functional activities of plants would be swept, together with those of animals, into its hands. Up to this time Section D had been the undivided section of Biology. An irregular cleavage of interests was set up by this claim, for the zoologists were mostly willing to give up their physiology, but the botanists were not. Their refusal to accept divorce of form from function contributed to, or at least coincided with, the foundation of a separate Section K of Botany, and has dictated the policy of British Botany ever since.

As we pass from 1894 to the current period we perceive a marked shifting of the interest of botanists from the study of form to that of the intimate constitution and functional activity of plants. Whole fields of colloidal chemistry and physics, of quantitative physiology, of cytology and genetics, of ecology, of fungology and bacteriology, have been opened up. The present century has been specially marked by the extension of opportunities for physiological research, by better equipment of departments in the universities, and by the foundation of independent establishments carrying on experimental inquiry in its broadest application. This is rapidly bringing the science into closer relation with Imperial and social aims. It is needless to specify, but the effect of it all is plainly written in the pages of the 'Annals.' Experimental results have gradually taken the preponderant place over description and comparison, as is amply shown in the last January number. 'For better, for worse,' the pendulum has definitely swung over from the extreme systematic position of half a century ago, through a phase of prevalent morphology (or perhaps we should better say of organography), to an extreme physiological position at the present time. Some of you may even have felt that this address is in itself an anachronism, in that it has not touched upon the moving physiological questions of the day. While I may claim none the less to sympathise with physiological aspirations, I do not

assent to any ultra-physiological aspect of botany that would degrade or minimise the comparative study of form. '*Medio tutissimus ibis*' is still a true maxim. The laboratory physiologist, dealing with the things of the moment, cannot safely detach himself from the things of the past as recorded in heritable form. He should not allow himself to be immersed in statistics and neglect history. The pendulum has gone full swing, within a period of about half a century; but we may confidently anticipate a return towards some middle position.

SECTION L.—EDUCATIONAL SCIENCE.

ADDRESS BY

SIR THOMAS H. HOLLAND, K.C.S.I., K.C.I.E., D.Sc., LL.D., F.R.S.,

PRESIDENT OF THE SECTION.

In the other Sections of the Association the Chair is reached normally after an apprenticeship and prolonged service in the ranks. This Section, devoted to Educational Science, has shown on the contrary a spirit of enterprise by recruiting as presidents some, at any rate, whose views on education must necessarily be a matter of nervous speculation on the part of the Sectional Committee.

From this I assume that those who are responsible for the development of this Section—all of them experienced in the art of education—are still searching for what the petrologists call a mineralising agent—some ideas which will facilitate the regular crystallisation of their observational data into an organised and orthodox science.

More than half of my distinguished predecessors have never professed an acquaintance with the forms of natural and physical science that occupy the attention of the other Sections; but the scientific method—the development of 'organised common sense'—is not limited to the data of what is popularly known as science: it equally follows the training of the classical scholar. So our aim is not the study of scientific education so much as the discovery of principles applicable to all forms of education. Nevertheless, for each of us in turn our experiences in testing methods of teaching must necessarily be limited to a single and relatively narrow branch of culture.

The teaching of science to students who have passed on to university classes has been my only experience of practical education, and the only generalisations that appear to me to be justified from a limited experience in this field are necessarily, in the first instance, applicable only to a sphere of short radius. I will confine myself to three such generalisations, and leave you to judge whether any part of them offers contributions of practical value to the art of training the younger generation to fulfil their duties as healthy and happy citizens.

In the first place I wish to submit for your consideration the results of our experience at South Kensington in practising the so-called 'tandem system,' and this is suggested because a colleague bred in other ways has described it as fundamentally rotten. Secondly, I should like to explore the possibility of introducing into scientific education some form of humanism which might neutralise the criticisms justifiably offered by classical students. Thirdly, I feel that the plea for the teaching of general

science, which was eloquently expressed by Sir Richard Gregory at Hull in 1922, has not yet received the practical appreciation in schools that it deserves.

With your permission I will give the results of my observations as judicially as possible; for, in spite of my limited experience in practical teaching, I do not feel inclined to be dogmatic.

Someone has given the appropriate name 'tandem system' to a form of curriculum in which the students are limited to one main subject, and one subject only, at a time. As an essential characteristic of this system the examination, which is final so far as the course is concerned, is taken immediately at the end of the course and before the next subject is taken up.

So far as I know, there is only one institution of university rank in this country in which this kind of curriculum is observed with any approach to rigidity, and that is the Imperial College at South Kensington, where it is still followed in the Royal College of Science and Royal School of Mines. The introduction of the system there is generally attributed to the late Professor Huxley; at any rate, the supposed virtues of the system were recognised and enforced during his tenure of office as Dean of the two joint colleges.

In the normal course for the diploma during Huxley's time, the student devoted his first half-session entirely to Chemistry, Part I; that is approximately the Pass standard of the ordinary B.Sc. He had one lecture each morning, spent the rest of the day in the laboratory, and in February took what was for that 'part' his final examination. During the second half-session the student was similarly confined to Physics, taking his final for Part I in June.

The second year was similarly taken in two halves, and then the student specialised in his main subject for the third year; but even in his third year Parts II and III, being distinct branches, were taken separately, with a final examination for the part at the end of each half-year. Thus, after the entrance examination or matriculation, the student took four main subjects of Pass standard, one of which was Part I of the third-year subject of a more specialised or Honours standard.

The only departure from this simple life was due to attendance for any necessary repairs and improvements required in Mathematics above that taken at the entrance examination. It was indeed a simple life, summed up in the approximately accurate formula—'One lecture each day; one subject one term.'

It is not necessary to trace the evolutionary history of the model commonly adopted for the ordinary university curriculum. The structure of any such course is in all essential respects similar to that of the ordinary secondary-school curriculum in requiring the consumption of two, three, or more subjects simultaneously. The graded 'forms' at school are continued under another terminology in the university—matriculation, intermediate, and degree final, or other local equivalents. The top of the school column and the lower grades at the university overlap one another in standard, and to various extents are interchangeable.

It will be sufficient to take as a fairly representative sample the regulations at any of the younger or so-called provincial universities. At

Manchester, for example, students who have matriculated are examined for the ordinary degree of B.Sc. in two parts—namely, the Intermediate and the Final. To sit for the Intermediate examination, candidates must attend a course of study at the University extending over at least one academic year in three of six defined science subjects, and must pass in either the three subjects at the same examination, or two subjects at one and the third at a subsequent examination. For the Final examination for the ordinary B.Sc., candidates must take two subjects, which are more specialised than at the Intermediate stage.

Training in *all* the subjects prescribed is spread over at least one academic year at each stage, and the examinations in all are held in one bunch at the end of the year or two years.

As the result of this system, students attend on the same day three and sometimes more lectures on distinct subjects, in different departments, and under separate professors; they may put in two or three hours of laboratory work in two unrelated branches each day.

This is the commonly recognised university system of training for the Science first degree in this country: it is assumed to be a suitable system, and those of us who have been compelled to spend some years in administration, requiring a rapid transfer of thought and action from one question to another of a quite unlike nature, realise that, for the development of mental fitness, the compound diet provided each day at both schools and universities has some strengthening qualities. But one rarely finds on inquiry among university teachers any real consciousness that the system is the product of a definite design or attempt to put into practice any recognised principles of education. University authorities assume, however, that to pass an examination in two or more subjects at the same time requires more mental nimbleness than when, as in the tandem system, the final examinations are taken at the end of each course in one subject only. This may be a simple guide for universities that have a strong external side and are thus driven to regard examinations as their only test. But the passing of examinations is not the only or, indeed, the ideal object of the university.

During the last four years, since returning from an intensive form of complex, semi-political administration to the more uniform atmosphere of academic life, in which barometric pressures are less liable to sudden variation, I have made a point of soliciting from experienced university teachers an estimate of the relative merits, as educational methods, of the commonly followed compound system on the one hand and of the so-called tandem system on the other as practised at South Kensington. My impressions have been gathered from witnesses who have followed approximately similar courses of training themselves; for most of the professors at South Kensington had been through the older universities and thus were themselves brought up on a mixed diet. Some of my colleagues confess to a clear recollection of coming to South Kensington with a definite prejudice against our system; but there is not one among them now who would give up the tandem system for that which is the commonly accepted practice elsewhere in this country.

The question was forced upon us recently in our attempt to persuade the University of London to accept our training and examinations for

their degree; and it was in these circumstances that I found, to my surprise as a newcomer, that in the Imperial College a very definite conviction had been formed in favour of the tandem system, a conviction so strong in some instances that certain of our professors would prefer the handicap of an independent set of degree examinations for their students rather than revert to the 'mixed' system.

I assume that for particular students both systems have their advantages, but in all forms of educational practice we are forced by limitations of time and staff to adopt systems that are most applicable to large groups, and one must remember that all of our students at South Kensington come from the same schools that feed other colleges, and all follow the 'mixed' method of training; the question that I am trying to answer is—Which for the average student of university standard is the better form of education?

The difficulties of changing over from one system to another are practically insuperable in any large college or university: it would necessitate the closing of the college for some three years, and then starting afresh with a clean slate. To advocate a general change-over seems out of the range of practical politics; but the merits of the two systems are nevertheless worth consideration for better than academic reasons; for one notices that, even within a single Honours school, the mixed system is adopted in most institutions, sometimes deliberately and in accordance with an assumed theory of education, sometimes merely because the 'mixed' diet is taken for granted as the right thing for normally minded students.

It is not possible now to adopt the tandem system as a whole in any long-established college working on the other more usual lines, but it is possible within most departments to adopt it for subjects which have grown so enormously in recent years that Honours schools in science have now to be subdivided. For example, in Geology the various subdivisions can be gathered into two groups—the petrological and the palæontological groups. Either group can be taken separately, and consequently, in an Honours course of two years after the Intermediate, students of the second and third year standard may be trained together, taking the petrological branch in one year and the palæontological branch in the next, instead of both branches simultaneously in two separate classes for second-year and third-year students respectively.

If there are merits in the tandem system the question is thus worth consideration for at least departmental use in most colleges and universities. It is not sufficient for those of us who favour the tandem system to assert that the other has merely grown without conscious guidance, and that vested interests and a complicated time-table now prevent reform. Among those whom I consulted during our recent discussion with the London University I found some experienced teachers who thought, and were honest enough to say, that Huxley took the wrong turning when he impressed his ideas on the old School of Mines and later College of Science.

With these opinions held generally outside and the contrary opinion held unanimously by our professors inside, there is obviously some justification for attempting an estimate of the relative merits of the two systems as alternative methods of treating the average student.

Since my time as a student at South Kensington, when Huxley was still Dean of the college, science has grown not by accretion but by multiplication. Our professors still adhere to the tandem principle, although one detects in the time-tables a slight yielding to the demands of the more complex life ; but an extension of the course from three to four years in most of the ' schools ' has helped still to preserve the simplicity of the student's night thoughts.

Candidates for the diploma and degree in Biology, for example, in their second year are compelled to take home with them twice a week an afternoon lecture on Biochemistry or Organic Chemistry as well as the morning lecture on Geology. Those who intend to specialise similarly in Geology for their finals are compelled during the first half of their second year every Friday to absorb a lecture on Zoology as well as one on Botany, and even after they enter the Geology Department finally for their third and fourth years, they have to attend more than one lecture a day, although always on some recognised branch of Geology itself.

Advocates of the tandem system claim that a student who has evening revision work to do is liable, when following more than one subject at a time, to give his extramural thoughts and study only to his favourite subject, and to trust to subsequent cramming for the others before his final examinations. They claim that a student should sleep only on one subject, preferably on one lecture only, in order that his subconscious cerebration may be effective in classifying data and in discovering principles for himself. An accessory advantage in a science department is the complete relief of some of the teaching staff from lectures and demonstrations for definite and fairly large sections of the academic session. This freedom from daily interruption facilitates research work by the staff, especially where extensive laboratory accommodation is necessary for their operations.

As I have said, an essential feature of the system is that the final examination in each subject or well-defined Part should be held at the end of the period of training in that branch. To undertake the teaching in tandem order and then to hold the examinations at the end of the full year, or, as in the Honours schools, at the end of two years, defeats the real object of the system ; for an examination impending in June on a course which ended in February distracts the student's mind from the subject taken between February and June. It is not the first subject which suffers by delay, but the second : the student suffers, not from want of memory-freshness regarding the subject in which his training ended last year, but by the disturbing influence of an examination menace which prevents his simple concentration on the later lectures and laboratory work.

It is not easy to equate the merits of these two systems, and it is impossible for one who has been brought up on the tandem system to avoid bias. For a subsequent career in which scientific research forms a major interest it seems fair to assume that the tandem system has a distinct advantage ; for a post-graduate career in business or administration, when many unrelated questions have to be handled daily and with promptness, one cannot help feeling that mental mobility is increased, or at any rate more rigidly tested, by the composite system of training and examination.

There are three main stages in the educational career of the average student—the primary or preparatory school, in which it seems desirable especially to arouse the interest of the boy; the secondary school, in which discipline might form the dominating note; and the university, in which more individuality is permissible, and the student should be given an opportunity of being more contemplative as specialisation approaches. It seems to me that if a student is expected to form his own ideas and to work out for himself the meaning of facts, his mental operations should not be disturbed by the rapid intake of unrelated groups of data. It is difficult for a housewife to put a room straight if the furniture is all put in before the carpet is laid; nor can picture-hanging and paper-hanging be carried on simultaneously.

Critics of the tandem system say, on superficial consideration, that if a student be examined in a subject finally and for good at the end of his first college term, he must necessarily forget the subject soon after and almost completely before the end of his third year. That is not in accordance with my observation. It is difficult, however, to obtain strictly comparative data on this point; for all observations are necessarily made on different students who would differ in any event; but my residual impression, as the result of the oral examination of candidates before Committees of Selection for appointments, is that the man who has been trained by the tandem system retains a clearer and cleaner recollection of his subjects than those who have been trained by the composite system. Whatever be the end in view—whether administration, business, or the academic life—it is important precisely to know what one knows and what one does not know.

There are special virtues in many systems of education: we have not yet discovered any that is universally applicable to the exclusion of others; and so with these two alternatives, which have been hitherto the main difficulty in fitting the Imperial College into the London University complex, each has its own merits. The institution of Honours schools is in itself a partial recognition of the tandem system, but we carry the principle much further at South Kensington by adopting it at an earlier stage and even in the Honours stage itself by subdivision of the final subject; and especially by holding examinations after each Part, instead of in a group of subjects at the end of the training.

When anyone engaged in practical education presses attention on a feature that he thinks to be too much neglected by others, it is not unusual to hear his principles spoken of as fads, which merely shows how far we have yet to travel before we can regard education as an organised science. This much is said to anticipate the label that some would use for my second point—the value of humanism in science teaching.

Under the tyranny of terminology our classical friends have usurped the 'humanities.' But they sometimes forget, through their specialisation in the purely rhetorical aspects of classical literature, that what gave rise to the Renaissance was the discovery of the long-buried wisdom, especially of the Greeks—their art, their religion, and their science. The revolt of the intellect from previous formalism and theological bondage resulted in more than the revival of literature and art, more than the religious freedom which gave us the Reformation: it aroused

curiosity regarding natural laws—what we now call the spirit of research, because the word curiosity is more widely occupied. The invention of the mariner's compass, and the exploratory spirit which accompanied it, led to the discovery of the Americas, South Africa, India and the Far East. The invention of gunpowder and that of paper and printing were the technological offspring of classical literature, strange as this may seem to us who see the wide gap between the modern classical school and the technical institute.

Some of the scientific developments which followed the classical Renaissance had possibly independent origins, but they were mainly the product of intellectual activities quickened by the rediscovery of buried philosophies. What would otherwise have been but slow combustion developed, because of the classics, with the speed of an explosion. Greek literature acted on mediæval scholasticism like nitric acid on combustible cellulose: cotton was converted into gun-cotton.

Thereafter followed the usual life-history of every organism: classical learning went through a phase of vigorous youth, vitalising the world with new energy and new ideas, till it reached the stage of adolescence and, with it, specialisation. With specialisation the study of the classics tended to become narrowed to its linguistic, grammatical, and purely rhetoric aspects: its main object became obscured and stricken with a formalism and even pedantry.

In the same way there is a danger, if not a noticeable tendency, in our study, and therefore teaching, of science so to produce by specialisation similar cultural ptomaines and thus to obtain what corresponds to the devitalised residue of the humanities without humanism.

In a thoughtful paper read in this city before the Congress of Empire Universities in 1921, Dr. C. H. Desch advocated the adoption of the historical method in teaching science. Emerson said that 'there is properly no history, only biography'; for history consists of innumerable biographies. Nothing appeals to a man like humanity; if we inspire the student's curiosity regarding the life-histories of our leaders, he will find out for himself the facts and principles of their science and technology.

Everyone here must recollect the time when he passed from the secondary school to the university; when he saw and met in real life men whose names he had heard before as objects of another world. Recalling the thrills of those days, one can understand why the professor's lecture was more inspiring than the more directly useful demonstration by a junior assistant in the laboratory. The professor, who has grown with his science, more naturally recalls the work of his contemporaries and immediate predecessors; and, until he reaches the stage of pure reminiscence, inspires his teaching by biography.

The educational balance is not secured by requiring students to attend a formal course of classics or history as well as of science. That would be merely to double the offence. Separate courses of history and science form a mechanical mixture as dead as the chemical constituents of protoplasm. It is the biographical history of science itself that contains the essential vitamins of the student's food. An illustration, possibly somewhat exaggerated, that I used here in 1924 will show what is intended: giving two separate doses of two unrelated subjects to act as mutual correctives

is equivalent to giving a patient a metallic-sodium pill with a sniff of chlorine gas, when what he really wants is a pinch of common salt. The two constituents given separately might be fatal, whilst the two in the form of the compound sodium-chloride make an essential food.

I have so far resisted the temptation to quote definitions of education, but perhaps at this stage of the Address one may be permitted. Sir Richard Gregory, in the Address that I have already referred to, defined education as the 'deliberate adjustment of a growing human being to its environment.' May I remind our teachers of science and technology that their students are not wanted only as experts in the laboratory and workshop?—they have post-graduate duties to perform as citizens, and must face relations—competitive relations—with other human beings, with most of whom they cannot communicate in technical terms alone. To be appreciated they must understand and be understood by others: they want the humanities, and the humanities are not the monopoly of the classical scholar.

My object in referring to the subject of Sir Richard Gregory's Address is not to revise his remarks or even to supplement them: it would be impossible for me to do either with advantage; but it is important that his advice should not be forgotten or displaced by influences altogether different from those of the principles which we are endeavouring to discover and use in teaching.

There are such influences at work moulding the trend of education without regard to its fundamental essentials. I find that most of those who enter the Imperial College as scholars have already attained a first-year standard in Chemistry, Physics, and Mathematics. These subjects form a considerable section of their school training and are thus used for purely commercial purposes—namely, the acquisition of scholarships. The candidates for scholarships seem to dictate to their teachers the educational principles which they should follow; and, through economic necessity, the teachers submit.

At the universities we close the vicious circle, admit the brilliant scholars to our Honours schools, and so produce a graduate in Chemistry or Physics who is blind for the rest of his life to what lies before him out of doors, where he ought to spend much, if not most, of his life. In the old days, when Sir Richard Gregory and I were together at South Kensington, a student could not obtain the College full diploma in any subject, not even in Mathematics and Mechanics, without passing through Part I Geology. Huxley and his colleagues believed that every man ought to know something of the history and origin of the features of the only world on which he will live in human form; and that without an acquaintance with those branches of science which are more observational than experimental no man should be regarded as an educated man.

Geology is now an optional not a compulsory foundation subject at South Kensington: the Imperial College has yielded to outside influences and the pressure which has followed the abnormal growth of each science, with the consequent demand for more time to be given to the final schools. Possibly, we turn out better Chemists, more specialised Mathematicians, and more efficient Physicists than we did in the old days; but I imagine that we run the risk of producing less valuable citizens who

are relatively happy only because they are blind to the beauties of the world around them. One pities the Wrangler as one does a deaf man at a concert, or a colour-blind man at a flower show.

Nature knowledge now is getting into the position that science generally occupied in the older classical schools: it is accessible only to the boy whose bent is too strong for the teacher, and who thus shows an individuality which tends to mark him down and so confirm his position as a freak. Possibly I am exaggerating, but it is obvious that scholarships are driving us to premature specialisation. The schools conform to the universities: each professor in the university pounces on the scholar and turns him to account as a recruit for his Honours school.

If I do no more than encourage some of you to read Sir Richard Gregory's Address again, my intrusion into this Section may be partially justified.

In an Address to the Universities Congress five years ago, Dr. Farnell, then Vice-Chancellor of Oxford, referred to as 'alarming' the recent decline of classical studies and their replacement by science, even at 'Oxford, the stronghold of Hellenism.'

This change-over to science and technology, dictated largely by utilitarian motives, is even more alarming to the teachers of science, whose agitation to this end has been embarrassingly successful; for the change brings with it a responsibility which was unforeseen in its fullness. When we remember that our chief public men and our army of administrators, here and overseas, who have made the British Empire what it is, have been trained mainly on classics, the duty of replacing them effectively falls on our teachers of science as a burden that they ought to feel as serious. That our classical teachers have been successful, even conspicuously so, is beyond question. Anyone who has had the privilege of watching the members of the Indian Civil Service carrying on the administration of their districts—with sympathy as well as efficiency, not here and there, but generally; not under the eye of the Press or of Parliament, but isolated, alone and unobserved—would seriously seek for the cause of their efficiency and character; for nine-tenths of the data employed in their early education has had no direct application to the problems that they have now to tackle.

I do not feel inclined to modify the words that I used here in 1924 in drawing the attention of teachers in engineering institutes to their new responsibilities—'Stresses set up by limitations of time and economic necessities force us, in modern educational institutions, to concentrate our attention on, and even in some instances to limit it to, professional and vocational subjects. But it is our duty to see that these stresses do not exceed the intellectual elastic limits of our students, and so be followed by mental strains.

'If the older system of classical education justified itself, not by the outturn of experts in the Greek and Latin languages, but by the development of character and capacity for affairs, we have to see to it that science and technology are also so taught that these essential features are developed, not inhibited, in the student.'

SECTION M.—AGRICULTURE.

THE RELATION BETWEEN CULTIVATED AREA AND POPULATION.

ADDRESS BY

SIR DANIEL HALL, K.C.B., LL.D., F.R.S.,

PRESIDENT OF THE SECTION.

Recent considerations of the problem of the capacity of the world to continue to feed its growing population appear to have begun with the late Sir William Crookes' address as President of this Association when he discussed the ultimate curtailment of the wheat supply through exhaustion of the soil nitrogen. Crookes' views attracted little more than academic attention at the time (1898), because the great tide of wheat that was setting in from the newer countries still in the process of exploitation was barely slackening; moreover, Crookes had neglected a factor then imperfectly appreciated—the fact that land under any of the conservative systems of farming adopted in the old settled countries does not become exhausted. The recuperative effects of the leguminous crops and the assimilation of nitrogen by soil bacteria like Azotobacter, have maintained unimpaired the fertility of European soils for perhaps thirty centuries of cultivation. Of course, reckless exploitation, such as the continuous growth of wheat and maize without any manuring, will eventually burn out the resources of even the prairie soils of the Middle West, and there is evidence that some of the long-cultivated Indian soils are losing fertility if only because dung and other residues which should go back to the soil are being burnt as fuel or sold away; but, generally speaking, a soil will maintain itself indefinitely at a certain level of production. Latterly in Europe that level has been raised by the introduction of extraneous fertilisers. In his review Crookes predicted the development of the synthetic processes of bringing nitrogen into combination which are to-day rendering that prime element of fertility so abundant and so cheap. But, though we no longer fear the exhaustion of soils, of late years certain sociological considerations have revived interest in the old thesis of Malthus. Over-population and unemployment have become terrible realities in this and other countries; many States are finding themselves under pressure to maintain their standard of living against the intrusion of neighbouring races propagating recklessly down to the barest margin of sustenance. Again, various studies of the course of prices of wheat have led to the conclusion that before the war the real price was rising continuously, and that this tendency is manifesting itself again, however much the true sequence of prices has latterly been obscured by fluctuations of currency. These considerations led Mr. Keynes to envisage the approach of scarcity: his attitude is very much a return to Malthus. On the other hand, Sir William

Beveridge, addressing the Economics Section two years ago, dismisses this fear as regards the world at large: whatever may be the troubles in Britain, 'the limits of agricultural expansion are indefinitely far.' On the whole that seems a very safe proposition; it has been so amply fulfilled for the last hundred and fifty years—during the greatest expansion of population the world has ever known—that it would almost seem to be necessarily true, especially as it can be buttressed by agricultural experiments showing the enormous potentialities of production from the soil.

There is, however, one aspect of the case that appears to have received insufficient attention: the capacity of agriculture to provide food for the people depends upon the extent of land available as well as upon the pitch of cultivation—to what degree can the tuning-up of methods be made to compensate for a non-expanding acreage? The first step towards a more exact consideration of the problem may therefore be an estimate of the amount of cultivated land that is required to maintain one unit of population—man, woman, and child.

We may make our estimates by either of two methods—abstract or actual. The Food (War) Committee of the Royal Society adopted the figure of 2,618 calories as representing the minimal daily energy requirement of one unit of the population, and calculated that the actual United Kingdom consumption in the five years 1909–1913 amounted to 3,091 calories per head per day. An average English acre of wheat yielding 32 bushels will produce food, in the shape of wheat, flour, and pig obtained from the offals, of a calorie value of about $2\frac{1}{2}$ millions. As the average consumption was about 1·13 million calories per head per year, we arrive at the conclusion that one acre of wheat would support more than two head, the relationship being more exactly 0·45 acre to feed one unit of population. But this figure is of no service in our more general consideration. The yield of wheat of 32 bushels per acre is far above that of the wheat-producing areas, and is that of only a few selected countries growing but a limited acreage. It is, again, the produce of land under the plough, and is consumed in the main as a vegetable product.

The great areas of grassland have a lower output of energy than the cultivated land, and the conversion of vegetable into animal food, whether of natural or cultivated fodder crops, is always attended by a great waste of energy. In the most economic production of pig-meat or milk the energy recovered is only about one-sixth of that consumed, and this represents the machine at the top of its efficiency. The longer period of beef-production results in a recovery as beef of only one-eighteenth of the energy consumed, and in practice the actual wastage of fodder and feeding-stuffs doubles or trebles the inevitable losses by conversion. And just as man is not a vegetarian making the most of the mere sustaining power of the land, so he does not use the land for food alone, but also for drink, for wool and fibre and other industrial materials, and for amenities. You may remember Maitland's argument that in the early mediæval times of Domesday Book and the two or three centuries following, about one-third of the arable land of the country was devoted to beer.

We shall not get far on the theoretical basis, and I have only mentioned it as indicating the order of the superior limit of the maintaining power of land.

We must approach the question in a more empirical fashion and endeavour to ascertain the existing relation between the land in use and the people fed by it. Taking again the estimates of the Royal Society's Committee, it concluded that the United Kingdom production of food for the five pre-war years was 42 per cent. of the food consumed. 46·7 million acres of cultivated land then produced 42 per cent. of the food consumed by a mean population of 45·2 millions, which works out to 2·5 acres to each unit of the population. This figure, however, is somewhat misleading, in that it does not do justice to British agriculture, since our farming is to a considerable degree concentrated on the more costly elements of diet like meat or milk rather than upon cereals and sugar. For example, 49 per cent. of the food production at home, as against only 24 per cent. of the imported food, consisted of animal products.

Working on a different basis, Sir Thomas Middleton estimated that 100 acres of British land fed forty-five to fifty persons, so that his estimate is over 2 but less than 2½ acres for the maintenance of the unit of population. Middleton proceeds to estimate that 100 acres in Germany fed seventy to seventy-five persons, or 1·3 to 1·5 acres per unit, the advantage being due on the one hand to a much higher proportion of arable land in Germany, and on the other to a dietary in which the energy was obtained more economically, *i.e.* from potatoes compared with meat, and in meat from pork rather than from beef.

The importance of this relation between cultivated area and population is so great, and the calculations by which it can be ascertained are so approximate and subject to so many estimates of a speculative kind, that I may be allowed to set out various results obtained by different methods.

We may begin by comparing population and area of cultivated land for all European countries except Russia, to which we add the United States, Canada, Argentine, Australia, and New Zealand, as the white countries which are also the chief exporters of food to Europe. I exclude all Oriental countries because in them the mass of the population possesses a different standard of living, and I have excluded the other South American States and the Union of South Africa and other African colonies because they all possess a very large 'native' population and their exports do not bulk large in the food account of Europe. We must recognise, however, that the errors in the calculation will be loaded on to one side, because all the unenumerated countries, Russia and the tropical lands, are to a greater or less degree exporters and not importers of food. Sugar from the East and West Indies, rice and similar Oriental cereals, copra and other edible oils for margarine, are but a few of the agricultural products which the white population consumes from land outside our immediate purview. However, with this proviso we find that in the States enumerated there are 464·1 million hectares of land under cultivation and a population of 481·5 million persons, or 2·4 acres per head.

In the United States about 356 million acres are in cultivation: from this may be deducted as producing exported materials, for cotton 24, for wheat 16, for maize 2, for meat products 22 million acres, or 65 million acres in all. Other products are exported but may be regarded as balanced by imports, so that we find 291 million acres of cultivated land devoted to supplying a population of approximately 112 millions, or 2·6 acres per unit of population.

France, we know, is a country that is largely self-supporting; it has a population of 39·3 millions and 36·3 million hectares under cultivation. To this acreage we must add 0·9 million for imported wheat, 0·5 for other cereals, and 1·1 for imported meat; the exports of wine and fruit we may regard as balanced off by other imports. The net result is approximately 1 hectare, or 2·4 acres, for each head of the population.

A similar calculation applied to Spain, a country in whose economy neither exports nor imports of food play a large part, gives over 4 cultivated acres per unit of population; but then the so-called 'cultivated' land includes a considerable proportion of mountain pasture of a very low order of productivity. On the other hand, Denmark,[1] with the most

[1] SUMMARY.

DENMARK, 1909-13.—Population (1911), 2,757,076; cultivated area, 7,957,000 acres

Cattle food units—millions.

Produced	6,648	Consumed vegetable	708
Imported	1,452	Seed	202
		Export as vegetable	90
		Animal food	7,100
	8,100		8,100

Allocation of animal food units.

	Available.		Consumed.	Exported.
Horses	1,194		1,194	—
Cattle	4,134	Milk 2,818	845	1,973
		Meat 1,316*	780	536
Pigs	1,706		580	1,126
Sheep	250		250	—
Poultry (eggs)	267		84	183
	7,551		3,733	3,818
Deduct for milk-fed	451		451	
			3,282	
			3,818	
	7,100		7,100	

* Corrected for meat import, 6,368 tons.

Food units (millions).

	Consumed.	Exported.
Vegetable produce	708	90
Seed	202	—
Animal produce	3,282	3,818
	4,192	3,908
	3,908	
	8,100	

1,452 food units were imported.

Net export is thus reduced to	2,456 food units	= 37%
Home consumption	4,192 „ „	= 63%
Home production	6,648	

63 per cent. of the home production is thus required for home consumption.
63 per cent. of the acreage 7,957,000 = 5,012,910 acres.

Population 2,757,076 = 1·82 acres per person.

highly developed agriculture of all countries, shows a production well above the average. A much closer calculation of production is possible for Denmark than for other countries—the data are set out in Mr. Harald Faber's paper before the Statistical Society in 1924. Denmark is a country exporting agricultural produce chiefly in its most costly form as meat, butter, and eggs, but the means for equating the export against consumption is supplied in Mr. Faber's paper by the reduction of production and imports to food units. Making the necessary corrections for imports, it would appear that for the years 1909 to 1913 the population of Denmark was maintained on 63 per cent. of the production of her own land, or 1·82 acres per person.

Putting the various estimates together, we arrive at the conclusion that under the existing conditions of agriculture among the Western peoples it requires something between 2 and 2½ acres of cultivated land to supply the needs of one unit of population living on the standard of white peoples.

We may confirm this estimate by a consideration of the growth of population during the last century. Between 1800 and 1920 the number of the white peoples increased from about 200 millions to about 700 millions. Data, however, for the land under cultivation in 1920 are very imperfect, and, again, there was another factor of improved agriculture which came into play in the first half of the nineteenth century. If we take 1870 as our jumping-off point, we may estimate the increase in the white man's numbers up to 1920 as approximately 225 millions. During the same period the addition to the cultivated lands in Europe, United States, Canada, Argentine, Australasia, and South Africa, the countries which have provided the white races with food, has amounted to about 450 million acres. Again we reach a relation between cultivated land and population of between 2 and 2½ acres per head.

This brings me to the central point of my argument, that an increase of population is in the first instance dependent upon an increase in the area of cultivated land. The expansion of the white peoples in the last century was an event unprecedented in the world's history, and was achieved only because of the vast areas of unoccupied land, chiefly in the Americas, which suddenly became available for settlement through the power conferred by the railroad, the steamship, and modern weapons. It will be noticed that the population of Europe previously had become comparatively stable, even as it has become approximately stabilised in France at present—the expansion came with the opening up of the new lands and in proportion to the amount that could be settled.

Accepting as a basis for further discussion that under the present system of agriculture something more than two acres of new land will have to be brought under cultivation for each unit of increase in the population; we may examine if any means exist of modifying this relationship before considering its consequences.

I have already suggested that a vegetarian diet is the more economical of the resources of the soil, and that meat and all animal products like milk and eggs are produced with an expenditure of energy which may be as low as seven but also as high as twenty times the energy available from them. It is true that to a certain extent the animal will utilise

material otherwise of little service to man, like milling offals and low-grade fodder crops—roots, hay, or straw. None the less, if the maximum of population supported by a given area of land is the objective, vegetarianism becomes increasingly necessary, as we see among the crowded populations of India and China. At the same time, the tillage of lands now given up to the grazing of animals becomes possible because of cheapness of labour resulting from a redundant population. Most of the beef and mutton supply comes from land left untilled because of the costliness of labour relative to products; the meat may represent a very low level of production from the land and yet a high cash return for the labour expended. Hence the apparent paradox of grazing being general in Middlesex because of the proximity of London. Another item of waste which would have to be eliminated in case of stern necessity is the conversion of potential food into alcoholic drink. Great Britain ferments the equivalent of one and a half million acres of barley. France devotes 4,000,000 acres, nearly 4½ per cent. of her cultivated area, to vineyards. Without going so far as to say that beer or wine possesses no food value, it is certainly not half of that which could have been grown from the land thus used for the production of drink. In such matters it is vain to prophesy, but I cannot help feeling that the race (not individuals) which cuts out meat and alcohol in order to multiply is of the permanent slave type destined to function like worker bees in the ultimate community.

The second question that merits very careful consideration is whether the current agriculture cannot be intensified so as to bring about a great increase of production from the existing area of cultivated land. A cursory examination of the average yields of our chief crops in different countries shows what an immense potential increase of production is here open. The average yield of wheat (1921 to 1924) for all the countries of the world collecting statistics was 13·2 bushels per acre; the average yield in Denmark for the same period was 41·4 bushels per acre, more than three times as much. Of course the area devoted to wheat in Denmark is about 200,000 acres in all, or 3 per cent. of her arable land, whereas the wheat acreage of the world amounts to about 250 million acres. The mass production of wheat in the world is from countries of low yield; more than half is grown in countries in which the average yield is less than 13 bushels per acre.

1924.	Total production million quintals.	Quintals per hectare.	Bushels per acre.
Russia	90	5·4	7·9
Canada	71	8·0	11·4
United States	238	10·8	15·5
India	99	7·8	11·1
Argentina	52	7·2	10·3
Australia	44	10·0	14·3
	594 (mean)	9·09	13·0

Recorded total . . 932 (estimated for all countries 1,250).

It is from these countries with the low yield per acre that wheat is exported and their production determines the world market, with the consequence that wheat production has been increasing in these and similar countries while it has been shrinking in the European countries with a higher yield per acre.

The dominating factor has been cost of labour; speaking broadly, it may be said that increased yields per acre are associated with higher expenditure per bushel for labour, and the great wheat-producing countries with a low yield per acre are the countries with a correspondingly high yield per man employed. It may be estimated that in England a man's labour produces about 960 bushels of wheat, in Australia 1,500 bushels. A more exact comparison shows that in England the labour cost amounts to 1*s.* per bushel of wheat, against 8*d.* in Canada, this with an average wage rate of 30*s.* to 36*s.* a week in England as compared with 60*s.* in Canada.

All this goes to show that intensification is only to be purchased at the cost of labour and that in the past extending the cultivated area has been a cheaper way of getting the wheat required by the world than by higher farming.

This general statement, however, does not tell the whole story; particularly it disguises the intensification of yield that may be obtained without a commensurate increase of labour. For example, the introduction of more heavily cropping varieties, originated by the skill of the plant-breeder, may add greatly to the production from a given area without increasing costs other than those of harvesting and marketing.

One must not, however, expect too much of the plant-breeder. Over the greater part of the cultivated land of the world the gross amount of production is limited by external factors such as water supply, temperature, available fertility of the soil, etc. For example, the plant-breeder seems to have had little or no power to increase the absolute production of *Beta vulgaris*; from all the forms of sugar-beet or fodder-beet (mangolds) on a given soil there is much the same yield of dry matter per acre, though in the well-bred sugar-beets the proportion that is in the useful form of sugar is greatly enhanced. The wheats and barleys grown in England had long been subjected to selection and improvement before the scientific methods of plant-breeding were evolved, and the further steps in improvement are going to be neither big nor easily won, depending as they do upon altering what Dr. Beaven has called the migration ratio, whereby the plant will convert more of the material obtained from the air into useful grain and leave less as straw. The chief opportunities, in fact, lie in the elimination of susceptibility to disease or destruction by frost, or general tenderness of constitution, by which means the range of the high-yielding cereals or even of cereal growth at all may be enormously extended. Absolute yielding power is perhaps less in question than productive capacity in relation to the environment.

The general enhancement of production by processes which induce improvements of the water supply or the temperature, as by irrigation and drainage, soil amelioration, cultivations, etc., suffers from the disadvantage of calling for labour, until it may prove far more costly than the increased produce can repay. Fertilisers appear to offer more promise. It may be recalled that the general level of production from English land was raised by nearly 50 per cent. between 1840 and 1870. At the beginning

of the period the average yield of wheat was of the order of 20 bushels per acre, this being the crop the land was capable of maintaining under a conservative rotation with no extraneous source of fertility. But between 1840 and 1870 artificial fertilisers were introduced and became a generally accepted part of British farming, with the result that the yield of wheat had risen to about 30 bushels per acre, though no other marked change in the routine of cultivation had been adopted during the period. The employment of fertilisers still lags far behind the opportunities of employing them to profit; from 1870 onwards came the great depression upon British agriculture consequent on the growing irruption of the cheaply grown American corn and meat. British agriculture had to shorten sail and restrict expenditure; falling prices breed lack of confidence and even lack of knowledge, for why should a farmer study a science that calls for expenditure when the safer procedure is to let the land grow a small crop without cost rather than to buy a big crop at a dangerous price? At any rate, our employment of fertilisers continues to be unnecessarily low even under later conditions of prices, and the revolution that is being brought about in the production of nitrogenous fertilisers finds our farmers comparatively disinclined to take advantage of it. The various processes of bringing atmospheric nitrogen into combination to which the war gave such a stimulus are now being developed on a vast scale in all civilised countries, and will result in an almost unlimited increase in the amount of nitrogenous fertiliser available at low prices compared with the prices of agricultural produce. Here at least is the opportunity for another step up in production from our cultivated lands comparable with the progress that was made between 1840 and 1870. It is not all plain sailing; the farmer has to study carefully where an increased supply of the cheapened nitrogen can be most suitably applied to his land and what changes in his system of cropping are demanded. The plant-breeders' art is needed; on most of our land any great enhancement of growth of cereals brought about by the use of nitrogenous fertilisers is attended with the danger of lodging. Few of our cereals possess stiff enough straw to remain standing on a soil enriched to the degree even that is reasonably practicable to-day. Thus the more immediate outlet for the new fertilisers would appear to be the fodder crops which are convertible into meat and milk.

But in the solution of the main problem under discussion—the possibility of intensification of production from the existing farmed land to meet the needs of a growing population—the development of the synthetic nitrogen fertilisers must play a dominant part. Crookes' prophecy is coming true.

I have reserved until the end the question of whether the intensification is necessary or probable. From previous experience it would appear to be probable that as long as new land is available the increase in food supplies will be won less by increased skill and expenditure applied to existing land than by taking in new land. The recent history of United States land affords an illustration; we see little improvement in farming or increase of yield on the older land—we see even abandonment of farms in the eastern States; at the same time we see continued attempts to win new land by forcing into cultivation the arid lands and alkali soils which the earlier settlers had rejected.

All over the world it always astonishes the traveller to see on what bad lands the new settler is now trying to farm. Evidently the good, easy virgin land is no longer easy to find. It is indeed significant that in the United States vast irrigation schemes are being carried out, though they show little signs of paying interest on their construction; that in Canada new wheats are being acclaimed because they may extend settlement into regions where killing frosts may be expected in August; that 'dry farming,' with a crop in alternate years only, has to be resorted to in Australia and S. Africa. These facts would seem to show that land is getting short in the world, at any rate the naturally productive land like that over which the great expansion of the nineteenth century proceeded. Where are we to find the 500 million acres of land such as was added to the world's farm between 1850 and 1900?

In Europe there are still great areas of forest, swamp, and heath that might be brought into cultivation, but the process would involve an expenditure both of initial capital and continuing labour out of proportion to the returns. Either the prices to be received for produce must rise greatly or the cultivators must be content with a much lower standard of remuneration before there is much addition to the European area under cultivation. In fact, the present tendency is in the other direction—only Italy, with its great pressure of population increase, is adding to its farming land and reclaiming wastes. All over the poorer land of Great Britain abandoned holdings and crofts may be traced, abandoned for economic reasons alone, because men would no longer live and work so near to the starvation level. Nothing but the direst need or a new scale of prices, whereby agriculture becomes relatively the most paying industry, will ever bring such land back into cultivation. Other European countries to a less degree show the same tendency at work. Russia was one of the granaries of Europe, but over a large proportion of that vast territory production is precarious because of drought on the one hand and cold on the other. It may be doubted whether there will be any great surplus for export even when its agriculture has been fully resumed, so rapid had been the growth of its population to a magnitude which makes the losses of the last decade insignificant.

In the United States there are still great areas of potential farming land; for example, O. C. Baker ('Economic Geography,' 1925) estimates a possible increase of the wheat area in the U.S.A. from the present 80,000 to 130,000 square miles. But little of this, however, is the natural easily farmed land the settler looks for; the drift of late years of American farmers to Canada, the efforts to make good the arid lands by dry farming and irrigation, show that the good land has mostly been taken up. What remains is land on which capital outlay is required, land on which production will always be more costly than on the great fertile plains of the Middle West. As in Great Britain, the recent tendency in the United States has been to abandon the cultivation of some of the poorer lands and let them fall back to grazing. Canada still presents enormous potentialities for settlement, though the vast areas the map reveals are severely restricted by increasing aridity towards the west and by cold northwards; Baker considers an increase of the wheat area from 25,000 to 120,000 square miles as physically possible. But similarly on most

of this land the wheat will have to be more dearly bought by labour, fertilisers, and skill than on the land now being farmed.

The potentialities of South America are less easy of estimate, but in this region there is still a great area of rich plain country unsettled, and it is not too much to expect that another 40 million acres of land are available for farming under present conditions.

The potentialities of non-tropical Africa and of Australia are small; in the latter country the arid zone lies so near to the coast that the additional area available for normal cultivation is negligible in considering the world's need of food. The great unknown factor in this survey is Western Siberia, a natural wheat area, and Manchuria. All that can be said is that the physical possibilities are great, perhaps as high as 300 million acres, but no one can guess when that will be realisable, dependent as it is upon the establishment of a stable and ordered Government. Moreover, on the flank of these regions hang the vast unsatisfied populations of China and Japan, ever ready to expand as the means of sustenance permits, and on this account the expectation of food for the Western peoples from this area can be but small. It is noteworthy that the far-eastern countries, so far from contributing to the food supply of the European peoples, have themselves of late years become competitors for wheat in the world market to an extent that has had a decisive effect upon prices.

As potential sources of food there still remain the tropical countries, in particular Brazil and Central Africa, where abundant rainfalls and high temperatures render feasible a very high level of production from the soil. The last fifty years has witnessed remarkable examples of organised production of tropical crops under western direction and management. The growth of sugar in Java, Cuba, and Hawaii, of rubber in Ceylon and the Straits, of tea in Ceylon and Assam, afford examples of the possibilities of organised agriculture, employing the resources of science, the labour-saving power of machinery, the criticism of cost book-keeping, such as can rarely be paralleled in the farming proper of the temperate regions. The same organisation is being extended to the coconut, which as margarine is becoming one of the chief edible fats of the world. Without doubt the tropics present enormous potentialities of food production for the world, mainly in the direction of oil-seeds and edible beans. It must, however, long remain uncertain to what extent the cheap native labour upon which these tropical exploitations are dependent will continue to be available. It does not appear to be possible to maintain a white population itself engaged in the cultivation of the soil in contact with native labour, and Queensland is the only tropical country where agricultural development is being attempted with white labour only. The lesson of S. Africa and to some extent of the southern States of the U.S.A. would seem to be that the white races cannot expand agriculturally in competition with the black.

The present annual increment in the white population may be estimated at about five millions. This, taken alone, would necessitate the taking into cultivation of twelve million acres of new land every year. No process of the kind is going on; indeed, for many crops there has been an actual shrinkage in the acreage since the war. Full records are not available, but the following table shows the changes in the areas of some of the main crops:—

CHANGES IN AREA UNDER CROP. MILLION HECTARES.

	1909/13	1921	1922	1923	1924
Wheat	107·8	103·5	99·5	104·0	105·6
Rye	44·3	37·0	40·7	44·6	43·9
Barley	33·3	29·4	27·3	30·9	30·7
Oats	57·4	55·1	50·7	53·8	55·8
Maize	70·6	71·7	73·0	74·1	(75)
Rice	47·8	53·0	53·3	51·8	52·8
Potatoes	15·3	14·8	15·3	16·2	16·6
Sugar Beet	2·3	1·7	1·7	2·0	2·6
	378·8	366·2	361·5	377·4	383·0

The shrinkage is doubtless no more than a temporary matter, the backwater of the wild fluctuations of prices and values brought about by the war, but it does not promise well for that continued expansion of the cultivated area which the still growing population demands. Indeed, we may detect a new influence at work, the growing disinclination of the civilised peoples to continue in agriculture because of its small and uncertain returns as compared with other occupations. It appears to be a general experience that wherever by the extension of communications the industries or commerce come close to agriculture the latter declines and begins to lose its best brains, its capital, and its men. The lure of the cities is proverbial, but the fundamental factor is economic; unorganised agriculture cannot pay the wages obtainable in the organised industries. The decline in the agricultural population of Great Britain and the United States is the most marked, but it is significant that in France, where of all countries the farmer is most protected and prices have been maintained, the peasants are leaving the land for the growing industries, their places being taken, in the south at least, by Italian immigrants.

The flight from the land is manifest equally among the wage-earners of large-scale agriculture and among the peasants or family farmers in whose hands resides the greater part of the cultivation, whether in the old settled countries of Europe or the newer exploitations of America. Again and again it must be urged that the determining cause is economic; for the last half-century, save for the abnormal war-years, farming has not paid a return on the capital and labour expended comparable with that obtainable elsewhere. It has been said that even the American farmers of the Middle West, who cut prices for all the world, made no profits during the last half-century except those derived from the accretion of land values. And the peasant farmer, who counts neither the capital he has in the business nor the hours of labour he gives to his land, who in Europe is held to the land by secular tradition, finds agriculture unattractive as soon as the growth of industries and the spread of communications render an escape possible. If not the peasant himself, at least the sons look for an easier and less exacting mode of life.

At this stage it would be impossible to begin to diagnose the causes of the comparative unprofitableness of agriculture. Fundamentally it is due to the weakness of the farmer as a commercial unit; the smaller the farmer the more ruthlessly does he compete with his neighbours and reduce prices to a bare level of sustenance for his long hours of labour.

Even the large farmers who can put into practice some of the economies of an ordered industry are helpless against the large commercial organisations which pass on their produce to the customers. Always there is the peasant farmer to cut prices. The position of the imperfectly industrialised farms may be compared with that of the new factories a century ago : their processes are not sufficiently developed to enable them to compete with any certainty of success against the single-handed worker, the power-mill has not yet beaten the hand-loom.

I cannot, however, pursue this issue. I return to my original text, that if we are to continue to feed the growing population of the world on the present methods a continued expansion of the cultivated area is required ; new land is called for year after year. I cannot see where this new land of the necessary quality is to be found in quantities commensurate with the immediate demand. Doubtless the white races will insist on maintaining their rising standard of living and will apply deliberate checks to their fertility, a process we already see in action. But the restriction of increase will not take effect all at once even under economic pressure, and the danger lies in the period preceding the comparative stabilisation. As it cannot be supposed that the development of the civilised races can be allowed permanently to be checked by lack of food when food is obtainable, it follows that resort must be had to the intensification of production from the area already under cultivation. The means for that intensification are already in sight, more will be supplied with the advancement of research. Intensification, however, is in the main attended by a higher cost of production, and movement in that direction is likely to be slow until it is stimulated by a rise of prices. Organisation will have to be introduced into the industry, and it may be expected that organisation will take one or other of three forms. The farmer may be left as the producing unit, but his methods will be strictly controlled and standardised by the great selling corporations that handle his produce, and these corporations may be either commercial ventures or co-operative associations of the farmers themselves. The co-operative venture appears to imply an even more rigid discipline of the individual than that imposed by the capitalist firm. Alternatively the capitalist may venture upon the direct exploitation of large areas of land and industrialise farming as he has industrialised other producing businesses. But capital will only be tempted back to farming, whether for the organisation of the business or even to enable the individual to take advantage of the possibilities of intensification, if prices rise to a definitely remunerative level. I hope I have given reasons for supposing that they must rise, because the surge in population set up by the unprecedented extension of the cultivated area last century cannot all at once be checked, whereas the new land still available is either inadequate in amount or unsuited to cheap production by the old methods. How close at hand the period of pressure may be it is unsafe to prophesy, but it may be agreed that pressure is sooner or later inevitable and that one of the biggest problems before the world at present is to prevent the pressure developing suddenly or becoming unbearable. The intensification of production is the only remedy, and, again, the only means of rendering intensification practicable is the continued pursuit of scientific research.

REPORTS ON THE STATE OF SCIENCE,

ETC.

Seismological Investigations.—*Thirty-first Report of Committee* (Prof. H. H. Turner, *Chairman*; Mr. J. J. Shaw, *Secretary*; Mr. C. Vernon Boys, Dr. J. E. Crombie, Dr. C. Davison, Sir F. W. Dyson, Sir R. T. Glazebrook, Dr. Harold Jeffreys, Prof. H. Lamb, Sir J. Larmor, Prof. A. E. H. Love, Prof. H. M. Macdonald, Dr. A. Crichton Mitchell, Mr. R. D. Oldham, Prof. H. C. Plummer, Mr. W. E. Plummer, Rev. J. P. Rowland, S.J., Prof. R. A. Sampson, Sir A. Schuster, Sir Napier Shaw, Sir G. T. Walker, *and* Mr. F. J. W. Whipple). [*Drawn up by the Chairman except where otherwise mentioned.*]

General.

As a sequel to the death of Mrs. Milne in 1925, as announced in the last Report, the sum of £1,000 bequeathed to this Committee by John Milne (provided that his widow should have the use of it during her lifetime) has been paid to the Chairman of the Committee, and is at present on deposit at the Westminster Bank, Oxford. The words of the Will are as follows :—

'And from and after her death (*i.e.* Mrs. Tone Milne) my Trustees shall stand possessed of my residuary estate and the income thereof upon trust to pay thereout the sum of £1,000 to the fund created by Matthew H. Gray, of Lessness Park, Abbey Wood, in the County of Kent, to be used by the Chairman of the Seismological Committee of the said British Association by the Trustees of that fund for the encouragement of the study of earth physics and its attendant subjects (the said sum to be paid free of legacy duty and the receipt of the said Chairman or Trustees for the time being to be a sufficient discharge of such legacy).' . . . .

The occasion suggested a reconsideration of the Trusteeship of the Gray Fund, into which the Milne Bequest is by this clause to be paid, and Messrs. Murray, Hutchins and Co. (the solicitors to the late Matthew H. Gray) suggested to the Committee that, to save the trouble and expense connected with the change in Trusteeship when any member of the Trust dies or retires from it, the Official Trustee of Charitable Funds should be asked to be Trustee of the Gray Fund. The approval of the Committee for this course is practically assured, though replies from one or two members of it have not yet been received.

Dr. Crombie has again generously provided half the salary of Mr. J. S. Hughes. The provision of the other half by the Department of Scientific and Industrial Research was terminated in September 1925.

We have again to acknowledge the help of Fordham University, New York, in sending telegrams on the occasion of important earthquakes, which have much facilitated the identification of epicentres. A notable example is that of the earthquake near Crete on 1926 June 26d. 19h. 46m. 20s. The Oxford film was developed on Sunday morning, June 27, and the receipt of telegrams from Fordham and West Bromwich made it possible to telegraph that afternoon an approximate epicentre. A message from Helwan next morning added considerable precision. The occasion was, unfortunately, one where the loss of life and the nature of the damage done (*e.g.* to the Candia Museum) gave special importance to the earthquake.

In Dr. C. Davison's *History of British Earthquakes*, noticed in the last Report, the little town of Comrie is conspicuous as an earthquake centre. An opportunity offered for visiting Comrie last August, as mentioned below ; and it was found that the earthquakes had ceased, rather to the chagrin of the inhabitants. But there were renewed shocks on February 22 and February 23.

International.

There is little to report under this head, except that the publication of the International Scientific Summary has been continued as below.

The serious fall in the value of the franc, in which international subscriptions are paid, has had a disastrous effect on the funds available for such work as the printing of the International Summary, which has only been relieved by the intervention of the Royal Society.

The Geodetic and Geophysical Union is to meet at Prague next year (1927), though as yet nothing has been said about the date ; it seems imperative to reconsider the whole question of finance.

Instrumental.

(*Chiefly from notes by Mr. J. J. Shaw.*)

The attempt to get seismological observations made at Christmas Island (Indian Ocean) has unfortunately proved a complete fiasco. It seems desirable to record the circumstances briefly. First we give the Report of Mr. H. S. Jones, now H.M. Astronomer at the Cape Observatory, who kindly took charge of the instrument.

Christmas Island Eclipse Expedition.

Report on Seismograph, June 9, 1923, *by H. S. Jones.*

'The expedition from the Royal Observatory, Greenwich, to Christmas Island for the observation of the Total Solar Eclipse of September 21, 1922, took with it, at the suggestion of Prof. H. H. Turner, a Milne-Shaw seismograph, lent by Mr. J. J. Shaw. It was hoped that it would be possible to arrange for the seismograph to be left on the island, and for continuous observations to be carried on by employees of the Christmas Island Phosphate Company.

'The seismograph was unpacked after the erection of the astrographic telescope, and it was found that, owing to faulty packing, the clock dial had come adrift and had smashed up the timing contacts, besides doing other damage. Mr. Shaw was at once written to for information as to the manner in which the timing gear was intended to function, but owing to the infrequent mails to Christmas Island it was some months before a reply was received. With the assistance of one of the Phosphate Company's engineers the damage was then repaired and the clock put into going order.

'Careful investigation was made as to the most suitable site for the seismograph. The eclipse camp was at the south-east end of the island, the settlement being on the north-west side. A site near the settlement was necessary if the seismograph were to be left on the island. The settlement is on a narrow flat shelf facing the sea, with steep cliffs behind, and does not provide very suitable sites for the purpose. An attempt was made in several places to find a place where the pier for the instrument could be built up from the solid rock, but the depth of soil was in all cases too great.

'Ultimately a site was chosen near the thermometer screen, somewhat sheltered by a large rock and by coconut palms, so as to reduce as much as possible the temperature variations. A concrete pier was constructed, extending 2 ft. 6 in. below the surface. Owing to the shortage of carpenters on the island and the pressure of work for them, including the erection of a new hospital and two new bungalows, it was not possible to get a hut erected for the seismograph until early in September. This consisted of a wooden framework, covered with corrugated iron, with shuttered window and door. The seismograph was erected and adjusted, a few minor alterations which were found to be necessary being carried out. The clock was fixed to the side of the pier. Several trial sheets were secured before the observers left the island, which showed that the adjustments were satisfactory, although owing to the diurnal variation of temperature there was a tendency for the traces to run into one another.

'The two chemists in the employ of the Phosphate Company, who are responsible for the meteorological observations, undertook to carry on the records, changing the sheets daily and developing them once per week. The construction and adjustment of the seismograph was explained to both these gentlemen. Written instructions were left that the sheets should be sent monthly to Prof. Turner, who would be responsible for the supply of photographic paper after the stock taken with the instrument was exhausted.

'It may be added that the erection of the seismograph pier and hut is included in the work done for the Expedition by the Christmas Island Phosphate Company, the cost of which has been generously given by them as a contribution towards the expenses of the Expedition. As also the Blue Funnel S.S. Company conveyed the

instruments free of charge, there is no charge upon the Seismology Committee in connection with the erection of the seismograph at Christmas Island.'

As no records were received at Oxford, nor any answers to repeated inquiries (principally made through Mr. Jones), application was ultimately made, as suggested by Mr. Jones on March 17, 1925, to the Secretary of the Phosphate Company at the London office, that the seismograph and clock might be returned to Mr. J. J. Shaw. They were received by him free of charge, but in a very much damaged condition; corrosion had attacked many of the metal parts, and the wooden cases were ruined by some form of dry rot. The instrument is being thoroughly repaired, and will now be lent to the Colombo Observatory.

The original Milne-Shaw instrument set up at Bidston, which has been replaced by another with larger magnification, is to be set up at Oxford as a N.-S. component, being similar to the E.-W. component already mounted (by the courtesy of Prof. Lindemann) in the basement of the Clarendon Laboratory. It seems now probable that a basement may be constructed at the University Observatory itself, to which this pair of instruments will then be transferred.

The two Milne-Shaw seismographs sent to Entebbe, Uganda, in 1923, which were awaiting suitable accommodation, have now been installed in a well-appointed observatory. The ground floor is used as the office, beneath is the dark room, and lower still (23 ft. below ground) is the instrument room. This should prove a very efficient station in a locality where one was much needed. There are a number of epicentres running down the African continent at which shocks occur which may not reach more distant observatories.

Seismographs have also been sent to Señor Scipion Llona, Director of the Seismological Observatory, Lima; also a second component to Fordham University, New York; finally to Prof. N. E. Norlund, Copenhagen, with a view to the establishment of a station in Greenland, which would be of great importance for the observation of earthquakes in the Arctic regions.

Bulletins and Tables.

The 'International Seismological Summaries' for April to December 1921 and January to September 1922 have been printed and distributed. The number for October to December 1922 is passed for press, with the exception of an appendix dealing with some belated observations. There are thus now five years of the Summary, 1918-1922, and the residuals for P and S shown by the chief earthquakes have been collected for discussion of the corrections to tables. The general nature of these corrections has already been anticipated from partial study of the records, but it is an important question whether we are in a position to make a definitive change, for it is undesirable to multiply changes. The answer is, on the whole, encouraging; the corrections to the P and S tables are clearly shown within about 1 second as far as $\Delta=80^\circ$. But beyond that point the correction to S is ambiguous; it seems that we are dealing with two phenomena and not one. The second phenomenon is easily identified as that designated S_cP_cS by Gutenberg many years ago. It represents the passage of a ray as S down to the liquid core; its passage as P through the core, and again as S on leaving the core. Attention was recently drawn to Gutenberg's papers by Dr. Harold Jeffreys, and the accord between observation and this particular part of his theory is very striking. (Other parts have not yet been compared with our records.) Accordingly Dr. Jeffreys has written the following paragraphs for this Report:—

The Earth's Central Core.

By Dr. Harold Jeffreys.

The high mean density of the earth, in comparison with that of surface rocks, has long been held to imply that the earth has a dense metallic core, probably mainly of iron. From considerations relating to the figure of the earth Wiechert determined the radius of this core as $0{\cdot}78a$, a being the outer radius, and its density as 8·2. Oldham in 1906 found that the compressional waves from earthquakes showed a systematic delay when observed at epicentral distances greater than 103° or so, and inferred that within a central region the velocities of these waves were lower than elsewhere. Subsequent work of the greatest importance by Gutenberg has strongly confirmed and extended Oldham's result. There is a central core of radius $0{\cdot}55a$, which transmits P waves with about two-thirds of the velocity they have just outside it, but does not transmit S waves at all. Several incidental phenomena implied by the existence of

such a core have been confirmed. A distortional wave incident on such a surface from above would give rise to reflected compressional and distortional waves, and to a transmitted compressional wave. The former are denoted by Gutenberg as S_4P and S_4S. The latter, on emergence, is again broken up into a compressional and a distortional wave; these are called S_4P_4P and S_4P_4S (in later work the suffix 4 is replaced by c). These transmitted waves with change of type are found on the seismograms at the predicted places and times. So is a wave that emerges after having undergone a reflection at the inside of the region. The waves reflected at the outside of the core are so spread out as to have only small amplitudes when they emerge, but Prof. V. Conrad has found waves that are capable of this interpretation.

The velocity of P waves, as found from near earthquakes, is nearly 7·8 km./secs., which points to a rock of the nature of olivine within a few tens of kilometres of the surface. Its density would be about 3·4. But at a depth of the order of 1,500 km. such a rock would be so compressed by the weight of the overlying rock that its density would be increased by about unity; the density of the iron core would be increased still more. Hence Wiechert's numerical results need revision, and it is found that when the increase of density due to compression is taken into account the boundary between the rocky shell and the iron core must be almost exactly where Gutenberg finds the discontinuity of elastic properties to be situated. The failure of the core to transmit S waves is most naturally attributed to its being fluid. Such a view has been denied, because it was found by Kelvin that the earth's tidal properties showed that as a whole it possessed about the rigidity of steel. But seismology now indicates that the rocky shell has a mean rigidity about twice that of steel, and reopens the possibility of a fluid core. In an investigation just published the present writer finds that the tidal data definitely imply a rigidity of the core much lower than that of the shell; if both the core and the shell were homogeneous, and the core fluid, the tidal yielding would be somewhat more than is observed, but allowance for variation of density within the layers would reduce the discrepancy, and it seems very probable that the core is truly fluid.

Gutenberg's S_cP_cS.

Of the waves or rays mentioned above by Dr. Jeffreys, the only one which has received attention up to the present in the discussion of 1918-1922 is that denoted first S_4P_4S and then S_cP_cS. By a curious coincidence this had attracted attention in a particular earthquake, October 11, 1922, the night before a letter from Dr. Jeffreys drawing attention to Gutenberg's work was received. The accord with observation is so close that the following extract from a note to that earthquake in the International Summary may be reproduced here:—

NOTE TO 1922 OCT. 11d. 14h. 49m. 45s.

The readings for S from near $\Delta = 80°$ to about $\Delta = 110°$ probably refer to something preceding the true S. The residuals can be represented by the formula :—

$$-(\Delta - 80°) \times 4{\cdot}6\text{s.}$$

Δ °	O.	C.	O−C.	Δ °	O.	C.	O−C.
81·4	− 6	− 6	0	94·1	−64	−65	+ 1
81·6	− 8	− 7	− 1	94·4	−62	−66	+ 4
83·3	−24	−15	− 9	95·0	−68	−69	+ 1
83·6	− 9	−17	+ 8	95·5	−65	−71	+ 6
84·5	−19	−21	+ 2	95·7	−65	−72	+ 7
88·0	−35	−37	+ 2	95·7	−76	−72	− 4
88·4	−31	−39	+ 8	96·5	−76	−76	0
89·4	−72	−43	−29	97·0	−77	−78	+ 1
90·6	−65	−49	−16	97·4	−77	−80	+ 3
90·8	+48	−50	(+98)	98·1	−97	−83	−14
91·1	−18	−51	(+33)	98·2	−84	−84	0
91·2	−52	−52	0	100·9	−96	−96	0
91·5	−51	−53	+ 2	103·2	−106	−107	+ 1
91·8	−45	−54	+ 9	103·5	−112	−108	− 4
92·3	−56	−57	+ 1	104·4	−112	−112	0
92·3	−41	−57	+16	104·7	−119	−114	− 5
92·9	−52	−59	+ 7	109·8	−142	−137	− 5
93·9	−64	−64	0	115·3	+75	−162	(+237)
				120·8	−98	−188	(+90)

These results had just been tabulated when a letter was received from Dr. Harold Jeffreys calling attention, in enthusiastic terms, to Prof. Gutenberg's paper *Erdbebenwellen VIIa*, in *Gott. Nach.* 1914, and it was at once seen that the readings tabulated as S refer to Gutenberg's ray S_cP_cS; that is, a ray which travels as S until it reaches the liquid core of the earth, is then transformed into P, and finally emerges as S. Since the middle part of its path is described with the velocity of P, which is greater than that of S, it naturally arrives before S. The figures given by Gutenberg compare with the adopted tables for S as below :—

Δ	54°	65°	70°	77°	79·5°	87·0°	94·5°	102°
	s.	s.	s.	s.	s.	s.	s.	s.
S_cP_cS	1175	1260	1295	1341	1348	1395	1442	1480
S	1029	1165	1226	1309	1338	1421	1501	1575
S_cP_cS-S =	+146	+95	+69	+32	+10	−26	−59	−95
Formula =	+120	+69	+46	+14	+ 2	−32	−67	−101
Diff.	+ 26	+26	+23	+18	+ 8	+ 6	+ 8	+ 6

It will be seen that throughout the range $\Delta=80°$ to $\Delta=110°$, from which the formula $(80°-\Delta)\times 4{\cdot}6$s. was deduced, the difference between it and the value of S_cP_cS-S assigned by Gutenberg is constant at about +7s. It changes a little for values of Δ back to 54°, but this only means that the formula for the difference from S is only approximately linear ; and it is rather remarkable that the approximation should be so close. In this region S_cP_cS *follows* S, and is not very likely to be recorded.

But the large negative residuals from S were noticed in 1917 in discussing the observations of 1913 (*The Large Earthquakes of* 1913, *B.A. Seism. Ctee.*, 1917).

The last reference need not, however, be followed here. The main point is that for this particular earthquake nearly all the thirty-five observatories between $\Delta=80°$ and $\Delta=110°$ which attempt to record S, record S_cP_cS instead. There are only two possible exceptions, Bidston (+98s) and Honolulu (+33s), and of these the latter has a positive residual not much greater than the −29s for Barcelona. Since for these values of Δ S_cP_cS precedes S, and S is generally counted as the earliest indication of a change from P, it is easy to see how the earlier S_cP_cS is preferred to the real S, provided it is large enough. [For values of Δ less than 80° S_cP_cS follows S according either to Gutenberg's theory or the above suggested empirical formula ; and that S should then be preferred is equally natural.]

But it is not always that S_cP_cS is large enough to be mistaken for S, as can be seen from the counts of residuals for the principal earthquakes in the five years 1918-1922 now under discussion. It will suffice here to give the counts for every 10 sec. in S and every 5° of Δ, and to restrict ourselves to the groups near the maximum.

Nos. of S residuals for the years 1918-1922 :—

Δ	s. +30	s. +20	s. +10	s. 0	s. −10	s. −20	s. −30	s. −40	s. −50	s. −60
70° to 75°	13	29	68	45	20	7	2	1	4	
75° to 80°	13	41	95	92	12	13	4	7	7	
80° to 85°	7	29	106	126	43	15	9	6	2	
85° to 90°	5	12	47	83	67	57	32	12	4	
90° to 95°	1	3	2	12	15	13	19	20	20	

For greater values of Δ the maximum is shifted so much that we must start afresh.

Δ	s. −40	s. −50	s. −60	s. −70	s. −80	s. −90	s. −100	s. −110	s. −120	s. −130	s. −140
90° to 95° .	20	20	18	8	1	2	1	0	0	1	
95° to 100°.	6	18	19	24	13	16	3	1	1	2	
100° to 105°	4	5	13	16	19	19	16	14	3	5	
105° to 110°	2	3	1	2	2	5	12	13	10	1	

Thus for values of Δ between 75° and 85° the maximum is definitely near zero ; there are two large groups enclosing zero, and the fall on either side is rapid. Between 85° and 90° there are five comparable groups near maximum ; from 90° to 95° there are seven. This is the effect of the double max. for S and S_cP_cS. But then the S max.

practically drops out, leaving only the S_cP_cS. This work was done on cards, and it was easy to remove the cards referring to S_cP_cS. Those left showed something much later than S; but it seems better to say no more until the discussion is complete.

New Stations.

The number of observatories which send readings for inclusion in the International Seismological Summary continues to increase. In May 1923 a list of 165 was published, and in November 1925 a list of forty-six more. Seven more are to be added to date, making 218 in all. Some of these have dropped out of action, and some send only rarely, but even after these deductions the list is a long one. Among stations recently established, a special welcome is due to Sucre in Bolivia (19·0° S., 65·3° W.), which collaborates with La Paz (16·5° S., 68·1° W.). Many shocks in South America are too slight to reach many observatories, and a pair of stations not very far apart is very useful on such occasions. An even closer pair is formed by La Plata (34·9° S., 57·9° W.), and Chacarita (34·6° S., 58·5° W.). Readings from La Plata for the later months of 1922 were received just in time for inclusion in the number of the Summary before it was passed for press, and it is hoped that they will henceforward be available; but there is still a tendency to delay communication of the information. The Summary for October-December 1922 is being passed for press at the time of writing (July 1926), and is thus in arrear by three years and five months; an interval which was much larger just after the War, but has been steadily reduced at the rate of about six months per year. Its limiting value, however, will depend upon the most backward stations, for it adds greatly to the labour of producing the Summary when information is received at the last moment. Hence observatories are earnestly requested to send their readings as soon as possible.

Time Determinations.

Before and during the War the time-determinations at many of the outlying stations were undoubtedly faulty, which complicated the process of interpreting the readings. A great improvement in this respect has followed on the introduction of wireless time-signals, though we in Europe perhaps overestimate the facility of getting accurate time in this way. For instance, the table of readings for Dehra Dun for 1925 is accompanied by the note: 'The time is expressed in Indian Standard Time, which is five hours thirty minutes east. It is liable to error as great as thirty seconds.'

If this is the state of things at the headquarters of geodesy in India, there must be even greater uncertainty at more outlying stations. Moreover, even where wireless signals are available, so that the seconds may be trusted, the minutes or hours may go wrong. Indeed, it seems possible that confidence in the seconds has begotten a little carelessness about the minutes. Perhaps the mistakes are made in applying the longitude, though in these days of standard time this ought not to upset the minutes.

Visit to Comrie.

As above mentioned, a visit was paid in August 1925 to Comrie, in Perthshire, where sixty-eight earthquake shocks were recorded between 1788-1804, and over 300 shocks in the eleven years 1839-49. There followed, however, fifteen blank years, and only fifteen shocks in the years 1864-1898, with a couple more in 1920. The village seems to regret the cessation. As the local guide-book puts it: 'The district misses the gratuitous advertisement which these shocks gave. Thus it has been found advisable to bring the merits of the place before the public in ordinary up-to-date advertising style.'

Interest in earthquakes is, however, still maintained, and has been rewarded since my visit by a couple of renewed shocks (1926, February 22 and 23). There was, however, little of importance to be gathered on the spot. The 'earthquake house' where experiments were made is still in existence, and by the courtesy of the present owner of the property (Mr. Drummond) I was allowed to see it. There is now no trace of its former occupation—it might be an ordinary summer-house. Objects like small ninepins of various cross-sections were set up on the floor; the observations consisted in noting which of them fell and what was the direction of fall. Tradition preserves the memory of a complete fall and scattering of the pins which could be associated with nothing seismological, and was ultimately traced to a raid by boys.

A noteworthy remark was made by the driver of Comrie's one bus, who remembered several earthquakes. According to him the most noticeable feature of these earthquakes is the sound, which, once heard, cannot be mistaken. It definitely travels, at Comrie, from N. or N.W. to E. or S.E. Once he heard an indubitable earthquake sound and could feel no tremor at all, but two horses he was tending started violently and stopped dead, showing that they felt a tremor. 'They would not have stopped for a noise.'

Finally, I could find no knowledge of any records, which I thought might possibly have been preserved.

Calculation of Mathematical Tables.—*Report of Committee* (Prof. J. W. Nicholson, *Chairman*; Dr. J. R. Airey, *Secretary*; Dr. D. Wrinch-Nicholson, Mr. T. W. Chaundy, Dr. A. T. Doodson, Prof. L. N. G. Filon, Dr. R. A. Fisher, Profs. E. W. Hobson, Alfred Lodge, A. E. H. Love, and H. M. Macdonald).

The following tables referred to in the last Report have been completed :—

(*a*) Tables of Fresnel's Integrals. $S(x)$ and $C(x)$ to six places of decimals for the range of values of x from 0·1 to 20·0 by 0·1 intervals.

(*b*) Tables of the Confluent Hypergeometric function $M(\alpha, \gamma, x)$ for some thirty values of the argument x from 0·1 to 8·0, the parameter α ranging from $+4{\cdot}0$ to $-4{\cdot}0$ and γ having the four values $\pm \frac{1}{2}$ and $\pm \frac{3}{2}$.

(*c*) Tables of sinh x and cosh x to fifteen places of decimals, similar to those of sin x and cos x given in previous Reports of the Committee, x from 0·1 to 10·0 by 0·1 intervals.

(*d*) Corrections of Logarithmic and Bessel Function Tables: the corrections of Thoman's and Degen's Tables of Logarithms were communicated by M. F. J. Duarte, Geneva.

The publication of the tables of zeros of Lommel-Weber and Neumann functions is deferred.

For next year's Report it is hoped to submit further tables of the Confluent Hypergeometric and other functions.

Fresnel's Integrals, $S(x)$ and $C(x)$.

For small values of the argument x, from 0·1 to 1·5, $S(x)$ and $C(x)$ were computed from the ascending series, viz. :—

$$S(x) = \sqrt{\frac{2x}{\pi}}\left\{\frac{x}{3} - \frac{x^3}{7.3\,!} + \frac{x^5}{11.5\,!} - \frac{x^7}{15.7\,!} + \cdots\cdots\right\}$$

$$C(x) = \sqrt{\frac{2x}{\pi}}\left\{1 - \frac{x^2}{5.2\,!} + \frac{x^4}{9.4\,!} - \frac{x^6}{13.6\,!} + \cdots\cdots\right\}$$

From the tables of Bessel Functions of half odd integral order given to twelve places of decimals in the 1925 Report, $S(x)$ and $C(x)$ were found for integer values of x from 1 to 20 by the relations

$$S(x) = J_{\frac{3}{2}}(x) + J_{\frac{7}{2}}(x) + J_{\frac{11}{2}}(x) + J_{\frac{15}{2}}(x) + \cdots\cdot$$

$$C(x) = J_{\frac{1}{2}}(x) + J_{\frac{5}{2}}(x) + J_{\frac{9}{2}}(x) + J_{\frac{13}{2}}(x) + \cdots\cdot$$

Fresnel's Integrals, S(x) and C(x).

x	S(x)	C(x)	x	S(x)	C(x)
0·0	0·000000	0·000000	5·7	0·370576	0·398539 :
0·1	0·008404 :	0·252061	5·8	0·362122	0·412861
0·2	0·023720 :	0·355400	5·9	0·355200 :	0·427825
0·3	0·043422	0·433102 :	6·0	0·349852 :	0·443274
0·4	0·066518 :	0·496612	6·1	0·346105	0·459047 :
0·5	0·092366	0·550247	6·2	0·343968 :	0·474985 :
0·6	0·120465 :	0·596157	6·3	0·343438	0·490927 :
0·7	0·150396	0·635581 :	6·4	0·344493 :	0·506717 :
0·8	0·181782	0·669309 :	6·5	0·347100	0·522201 :
0·9	0·214277 :	0·697884 :	6·6	0·351207	0·537232
1·0	0·247558 :	0·721706	6·7	0·356752 :	0·551667 :
1·1	0·281317 :	0·741088 :	6·8	0·363659	0·565375
1·2	0·315262	0·756294 :	6·9	0·371839 :	0·578229
1·3	0·349113	0·767555	7·0	0·381194 :	0·590116
1·4	0·382604 :	0·775083	7·1	0·391614 :	0·600932
1·5	0·415483 :	0·779083 :	7·2	0·402982	0·610585 :
1·6	0·447511	0·779758 :	7·3	0·415171 :	0·618997 :
1·7	0·478462 :	0·777310	7·4	0·428051 :	0·626101 :
1·8	0·508128 :	0·771943	7·5	0·441485 :	0·631845
1·9	0·536316	0·763869	7·6	0·455332 :	0·636190
2·0	0·562849	0·753302 :	7·7	0·469451 :	0·639111 :
2·1	0·587568	0·740465	7·8	0·483698 :	0·640599
2·2	0·610333	0·725582	7·9	0·497931 :	0·640656 :
2·3	0·631022 :	0·708885	8·0	0·512009 :	0·639301
2·4	0·649534 :	0·690607	8·1	0·525795 :	0·636564 :
2·5	0·665787	0·670986	8·2	0·539157	0·632490 :
2·6	0·679717 :	0·650259	8·3	0·551966 :	0·627135 :
2·7	0·691284 :	0·628664	8·4	0·564104	0·620568
2·8	0·700466 :	0·606437 :	8·5	0·575457	0·612868
2·9	0·707260 :	0·583813 :	8·6	0·585923 :	0·604124
3·0	0·711685	0·561020 :	8·7	0·595409	0·594436
3·1	0·713776 :	0·538281 :	8·8	0·603831 :	0·583909 :
3·2	0·713591	0·515813 :	8·9	0·611119 :	0·572659
3·3	0·711200	0·493822	9·0	0·617213 :	0·560804
3·4	0·706695	0·472505	9·1	0·622066 :	0·548468 :
3·5	0·700180 :	0·452047	9·2	0·625644 :	0·535780
3·6	0·691777	0·432621 :	9·3	0·627925	0·522868
3·7	0·681618	0·414387	9·4	0·628899 :	0·509863
3·8	0·669849 :	0·397488	9·5	0·628573	0·496895
3·9	0·656628	0·382052 :	9·6	0·626962	0·484092
4·0	0·642118 :	0·368193	9·7	0·624096	0·471579
4·1	0·626495	0·356004 :	9·8	0·620015 :	0·459477
4·2	0·609935 :	0·345565	9·9	0·614774 :	0·447902 :
4·3	0·592623 :	0·336934 :	10·0	0·608436 :	0·436964
4·4	0·574746	0·330154 :	10·1	0·601074 :	0·426764
4·5	0·556489 :	0·325249	10·2	0·592772 :	0·417396 :
4·6	0·538040 :	0·322225	10·3	0·583621 :	0·408946 :
4·7	0·519583 :	0·321070 :	10·4	0·573721	0·401488 :
4·8	0·501299	0·321756 :	10·5	0·563176	0·395086 :
4·9	0·483362	0·324239	10·6	0·552097 :	0·389795
5·0	0·465941 :	0·328456 :	10·7	0·540600 :	0·385655 :
5·1	0·449197 :	0·334333	10·8	0·528803	0·382698
5·2	0·433280	0·341778 :	10·9	0·516825	0·380941 :
5·3	0·418330 :	0·350690	11·0	0·504786 :	0·380392
5·4	0·404476 :	0·360952	11·1	0·492807 :	0·381044
5·5	0·391833 :	0·372439	11·2	0·481007 :	0·382880 :
5·6	0·380504	0·385015 :	11·3	0·469500 :	0·385872 :

Fresnel's Integrals, S(x) and C(x)—contd.

x	S(x)	C(x)	x	S(x)	C(x)
11·4	0·458399 :	0·389980	15·8	0·599937	0·493920 :
11·5	0·447810 :	0·395152 :	15·9	0·598519 :	0·484005
11·6	0·437834	0·401329 :	16·0	0·596126 :	0·474310 :
11·7	0·428564 :	0·408441	16·1	0·592788	0·464933 :
11·8	0·420087	0·416408	16·2	0·588543 :	0·455964
11·9	0·412480	0·425144 :	16·3	0·583440 :	0·447489 :
12·0	0·405811	0·434557 :	16·4	0·577535	0·439591
12·1	0·400139	0·444547	16·5	0·570890 :	0·432343 :
12·2	0·395511 :	0·455010	16·6	0·563578 :	0·425815 :
12·3	0·391966 :	0·465838	16·7	0·555674 :	0·420067 :
12·4	0·389530	0·476920 :	16·8	0·547261 :	0·415152
12·5	0·388217	0·488146	16·9	0·538426 :	0·411113
12·6	0·388032 :	0·499401	17·0	0·529259	0·407985 :
12·7	0·388969	0·510574	17·1	0·519853 :	0·405795
12·8	0·391007 :	0·521554 :	17·2	0·510303 :	0·404558 :
12·9	0·394120 :	0·532234 :	17·3	0·500706 :	0·404282
13·0	0·398267 :	0·542510 :	17·4	0·491157	0·404963 :
13·1	0·403400 :	0·552283 :	17·5	0·481750	0·406590
13·2	0·409460	0·561460	17·6	0·472579	0·409140
13·3	0·416379	0·569954	17·7	0·463733 :	0·412583 :
13·4	0·424082 :	0·577685	17·8	0·455300	0·416880
13·5	0·432488	0·584583	17·9	0·447360	0·421983 :
13·6	0·441507	0·590585	18·0	0·439989 :	0·427837
13·7	0·451044 :	0·595638	18·1	0·433259	0·434379 :
13·8	0·461002 :	0·599698 :	18·2	0·427232	0·441541
13·9	0·471279	0·602734	18·3	0·421964 :	0·449247 :
14·0	0·481769 :	0·604721	18·4	0·417504 :	0·457419
14·1	0·492368	0·605647 :	18·5	0·413893	0·465971 :
14·2	0·502968	0·605511 :	18·6	0·411160 :	0·474818
14·3	0·513464 :	0·604322 :	18·7	0·409330	0·483869
14·4	0·523754 :	0·602099 :	18·8	0·408414	0·493032 :
14·5	0·533735 :	0·598871	18·9	0·408418	0·502217 :
14·6	0·543312	0·594677	19·0	0·409336 :	0·511332
14·7	0·552390 :	0·589565 :	19·1	0·411155 :	0·520285 :
14·8	0·560884 :	0·583593 :	19·2	0·413852	0·528990
14·9	0·568713	0·576826	19·3	0·417395	0·537360
15·0	0·575803 :	0·569336	19·4	0·421744 :	0·545314
15·1	0·582089 :	0·561203	19·5	0·426853 :	0·552774 :
15·2	0·587514	0·552511 :	19·6	0·432666 :	0·559670
15·3	0·592029	0·543352 :	19·7	0·439122 :	0·565935
15·4	0·595595 :	0·533819 :	19·8	0·446153 :	0·571510
15·5	0·598184	0·524010	19·9	0·453687 :	0·576342 :
15·6	0·599775	0·514023	20·0	0·461646	0·580389
15·7	0·600359	0·503960			

The tables were completed to nine places by interpolating to tenths of a unit of the argument, first differences being calculated from the known values of $J_{\frac{1}{2}}(x)$ and $J_{-\frac{1}{2}}(x)$. Lommel's tables of S(x) and C(x) appear in various collections of mathematical tables, although the last digits are unreliable in a considerable number of the entries. The difficulty in checking these results was due to the absence of adequate tables of sines and cosines in radian measure. Tables of these functions to fifteen places of decimals were published in the 1916, 1923 and 1924 Reports of the Committee.

The Confluent Hypergeometric Function. M $(\alpha . \gamma . x)$.

Attention has been drawn to the importance of this function* in the solution of differential equations of the second order

$$\frac{d^2y}{dx^2} + f(x) . \frac{dy}{dx} + \varphi(x) . y = 0,$$

where $f(x)$ and $\varphi(x)$ are linear, quadratic or other simple functions of x. In ascending powers of x, M $(\alpha . \gamma . x)$ is

$$1 + \frac{\alpha}{\gamma}x + \frac{\alpha(\alpha+1)}{\gamma(\gamma+1)} . \frac{x^2}{2!} + \frac{\alpha(\alpha+1)(\alpha+2)}{\gamma(\gamma+1)(\gamma+2)} . \frac{x^3}{3!} + \ldots\ldots$$

and satisfies the differential equation

$$x . \frac{d^2y}{dx^2} + (\gamma - x)\frac{dy}{dx} - \alpha . y = 0.$$

By changing both dependent and independent variables, it can be shown that differential equations of the type

$$\frac{d^2y}{dx^2} + (px+q)\frac{dy}{dx} + (lx^2+mx+n)y = 0$$

can be solved in terms of M $(\alpha . \frac{1}{2} . x)$. The exponential function appears in association with this function. Very extensive tables† of e^x and e^{-x} were published in the *Transactions of the Cambridge Philosophical Society.* Other differential equations which can be solved by means of the M functions are set out in the *Phil. Mag.* paper, *e.g.* Petzval's equation :

$$x^2\frac{d^2y}{dx^2} + x(p+qx^m)\frac{dy}{dx} + (r+sx^m+tx^{2m})y = 0.$$

Spitzer's equation :

$$\frac{d^2y}{dx^2} = x\left(x\frac{dy}{dx} - ny\right).$$

Laplace's equation‡ :

$$(a_2+b_2x)\frac{d^2y}{dx^2} + (a_1+b_1x)\frac{dy}{dx} + (a_0+b_0x)y = 0$$

$$\frac{d^2y}{dx^2} + \left(p+\frac{q}{x}\right)\frac{dy}{dx} + \left(l+\frac{m}{x}+\frac{n}{x^2}\right)y = 0.$$

The asymptotic expansion of M $(\alpha . \gamma . x)$ is

$$\frac{\Gamma(\gamma)}{\Gamma(\gamma-\alpha)} . (-x)^{-\alpha}\left\{1 - \frac{\alpha(\alpha-\gamma+1)}{x} + \frac{\alpha(\alpha+1)(\alpha-\gamma+1)(\alpha-\gamma+2)}{2!\,x^2} - \ldots\ldots\right\} +$$

$$\frac{\Gamma(\gamma)}{\Gamma(\alpha)} e^x x^{\alpha-\gamma}\left\{1 + \frac{(1-\alpha)(\gamma-\alpha)}{x} + \frac{(1-\alpha)(2-\alpha)(\gamma-\alpha)(\gamma-\alpha+1)}{2!\,x^2} + \ldots\ldots\right\}$$

The six difference relations may be used to extend the tables for other values of α and γ

$$x\,\mathrm{M}(\alpha+1 . \gamma+1 . x) = \gamma\,[\mathrm{M}(\alpha+1 . \gamma . x) - \mathrm{M}(\alpha . \gamma . x)]$$

$$\alpha\,\mathrm{M}(\alpha+1 . \gamma+1 . x) = (\alpha-\gamma)\,\mathrm{M}(\alpha . \gamma+1 . x) + \gamma\,\mathrm{M}(\alpha . \gamma . x)$$

$$(\alpha+x)\,\mathrm{M}(\alpha+1 . \gamma+1 . x) = (\alpha-\gamma)\,\mathrm{M}(\alpha . \gamma+1 . x) + \gamma\,\mathrm{M}(\alpha+1, \gamma . x)$$

$$\alpha\gamma\,\mathrm{M}(\alpha+1 . \gamma . x) = \gamma(\alpha+x)\,\mathrm{M}(\alpha . \gamma . x) - x(\gamma-\alpha)\,\mathrm{M}(\alpha.\gamma+1, x)$$

$$\alpha\,\mathrm{M}(\alpha+1 . \gamma . x) = (x+2\alpha-\gamma)\,\mathrm{M}(\alpha . \gamma . x) + (\gamma-\alpha)\,\mathrm{M}(\alpha-1, \gamma . x)$$

$$(\gamma-\alpha)x\,\mathrm{M}(\alpha . \gamma+1 . x) = \gamma(x+\gamma-1)\,\mathrm{M}(\alpha . \gamma . x) + \gamma(1-\gamma)\,\mathrm{M}(\alpha, \gamma-1 . x)$$

* H. A. Webb and J. R. Airey. 'The practical importance of the Confluent Hypergeometric Function': *Phil. Mag.*, vol. 36, July 1918, pp. 129-141.

† J. W. L. Glaisher. Tables of the Exponential Function : *Camb. Phil. Trans.*, 1883, vol. 13, part 3, pp. 243-272. F. W. Newman. Table of the Descending Exponential Function : *Camb. Phil. Trans.*, vol. 13, part 3, pp. 145-241.

‡ Laplace. *Théorie analyt. des probabilités.* Livre I, première partie.

For small values of the argument, the series in ascending powers of x were used in calculating $M(1 \,.\, \frac{1}{2} \,.\, x)$ and $M(-\frac{1}{2} \,.\, \frac{1}{2} \,.\, x)$ to nine places of decimals.

$$M(1 \,.\, \tfrac{1}{2} \,.\, x) = 1 + 2x + \frac{(2x)^2}{3} + \frac{(2x)^3}{3 \cdot 5} + \frac{(2x)^4}{3 \,.\, 5 \,.\, 7} + \ldots\ldots$$

$$M(-\tfrac{1}{2} \,.\, \tfrac{1}{2} \,.\, x) = 1 - x - \frac{x^2}{3 \,.\, 2!} - \frac{x^3}{5 \,.\, 3!} - \frac{x^4}{7 \,.\, 4!} - \ldots\ldots$$

Since $M(0 \,.\, \frac{1}{2} \,.\, x) = 1$ and $M(\frac{1}{2} \,.\, \frac{1}{2} \,.\, x) = e^x$, the recurrence relations may be applied at once to construct the rest of the table for these values of x and other values of the parameters, α and γ.

For larger values of x, the asymptotic series were employed, viz.:

$$M(1 \,.\, \tfrac{1}{2} \,.\, x) = e^x \sqrt{\pi x} + \left\{ \frac{1}{2x} - \frac{1 \,.\, 3}{(2x)^2} + \frac{1 \,.\, 3 \,.\, 5}{(2x)^3} - \frac{1 \,.\, 3 \,.\, 5 \,.\, 7}{(2x)^4} + \ldots \right\} \quad . \quad . \quad (a)$$

$$M(-\tfrac{1}{2} \,.\, \tfrac{1}{2} \,.\, x) = -e^x \left\{ \frac{1}{2x} + \frac{1 \,.\, 3}{(2x)^2} + \frac{1 \,.\, 3 \,.\, 5}{(2x)^3} + \frac{1 \,.\, 3 \,.\, 5 \,.\, 7}{(2x)^4} + \ldots \right\} \quad . \quad . \quad (b)$$

Both these series begin by converging, but eventually become divergent, and it was maintained that the approximation to the value of the functions could not be carried beyond the point where the terms begin to diverge, *i.e.* the calculation must not be taken beyond the least term.

'When the argument is at all large, the series at first are rapidly convergent, but they are ultimately in all cases hypergeometrically divergent. Notwithstanding this divergence, we may employ the series in numerical calculation, provided we do not take in the divergent terms.' §

'Series of this kind are, strictly speaking, not convergent at all, for when carried sufficiently far, the sum of the series may be made to exceed any assignable quantity. But, though ultimately divergent, they begin by converging; and when a certain point is reached, the terms become very small. Calculations founded on these series are, therefore, only approximate; and the degree of approximation cannot be carried beyond a certain point. If more terms are included, the result is made worse instead of better. In numerical calculations, therefore, we are to include only the convergent part.' ||

In the case of $M(1 \,.\, \frac{1}{2} \,.\, x)$, where the signs of the terms are alternately positive and negative, if $x = \nu + h$ and $\nu = n + \frac{1}{2}$, it can be shown that the asymptotic series becomes

$$\frac{1}{2x} - \frac{1 \,.\, 3}{(2x)^2} + \frac{1 \,.\, 3 \,.\, 5}{(2x)^3} - \ldots\ldots\ldots \pm \frac{1 \,.\, 3 \,.\, 5 \,.\,.\,.\,.\,.\, (2n-1)}{(2x)^n}(1 - \varphi_1),$$

where φ_1 is the 'converging factor.' The first six terms of φ_1 are

$$\frac{1}{2} - \frac{1}{4\nu}\left(\frac{1}{2} + h\right) + \frac{1}{8\nu^2}\left(\frac{1}{4} + \frac{h}{2} + h^2\right) + \frac{1}{16\nu^3}\left(\frac{1}{8} + \frac{h}{4} - h^3\right)$$

$$- \frac{1}{32\nu^4}\left(\frac{13}{16} + \frac{13h}{8} + \frac{7h^2}{4} + h^3 - h^4\right) + \frac{1}{64\nu^5}\left(\frac{47}{32} + \frac{47h}{16} + \frac{15h^2}{4} + \frac{15h^3}{4} + \frac{5h^4}{2} - h^5\right) + \ldots$$

When x is about 10, it is possible to add eight or nine decimal places to the result obtained when the divergent terms are omitted in the calculation from the asymptotic series (a).

For the function $M(-\frac{1}{2} \,.\, \frac{1}{2} \,.\, x)$, where the signs of the terms in the asymptotic series are all positive, a 'converging factor' may also be found. If $x = \nu + h$ and $\nu = n + \frac{1}{2}$, the descending power series in (b) is

$$\frac{1}{2x} + \frac{1 \,.\, 3}{(2x)^2} + \frac{1 \,.\, 3 \,.\, 5}{(2x)^3} + \ldots\ldots + \frac{1 \,.\, 3 \,.\, 5 \,.\,.\,.\,.\,.\, (2n-1)}{(2x)^n}(1 + \varphi_2),$$

§ Stokes. *Mathematical and Physical Papers*, vol. 2, p. 237.

|| Rayleigh. *Scientific Papers*, vol. 1, p. 190. Also Glaisher, *Phil. Trans.* London, vol. 160, pp. 367-387. Borel, *Séries Divergentes*, p. 3.

i.e. the divergent terms of (b) are represented by the product of φ_2 and the nth term: φ_2 is given by the series

$$e^{-h}\left(1+\frac{h}{\nu}\right)^{\nu}\left\{(b_0+h)+\frac{1}{\nu}\left(b_1-\frac{h^2}{2}+\frac{h^3}{6}\right)+\frac{1}{\nu^2}\left(b_2+\frac{h^3}{3}-\frac{5h^4}{24}+\frac{h^5}{40}\right)\right.$$
$$+\frac{1}{\nu^3}\left(b_3-\frac{h^4}{4}+\frac{13h^5}{60}-\frac{7h^6}{144}+\frac{h^7}{336}\right)$$
$$\left.+\frac{1}{\nu^4}\left(b_4+\frac{h^5}{5}-\frac{77h^6}{360}+\frac{17h^7}{252}-\frac{h^8}{128}+\frac{h^9}{3456}\cdot\right)+\ldots\right\}$$

where
$$\begin{aligned}
b_0 &= -0{\cdot}33333\ 33333\ 33\\
b_1 &= +0{\cdot}02962\ 96296\ 3\\
b_2 &= +0{\cdot}00282\ 18695\\
b_3 &= -0{\cdot}00188\ 1246\\
b_4 &= -0{\cdot}00071\ 196\\
b_5 &= +0{\cdot}00067\ 84\\
b_6 &= +0{\cdot}00047\ 3\\
b_7 &= -0{\cdot}00059\\
b_8 &= -0{\cdot}0006
\end{aligned}$$

In this case, an improvement may be effected in the approximation to the value of the function $M(-\frac{1}{2}\,.\,\frac{1}{2}\,.\,x)$, when x is comparatively small. Even with the short table of b_n given above, when $x=10{\cdot}5$, twelve places of decimals can be added to the result where the terms of the asymptotic series beyond the n^{th} are neglected. With more extended tables of b_n, the approximation has been carried to twenty places: when x has the small value $3{\cdot}5$, to ten places. When α is a negative integer, $M(\alpha\,.\,\gamma\,.\,x)$ reduces to a polynomial which is easily evaluated.

$\mathbf{M}\,(\alpha\,.\,\tfrac{1}{2}\,.\,x)$

x	$\alpha=\frac{1}{2}$	$\alpha=\frac{3}{2}$	$\alpha=\frac{5}{2}$	$\alpha=\frac{7}{2}$
0·0	+ 1·00000	+ 1·00000	+ 1·00000	+ 1·00000
0·1	+ 1·10517	+ 1·32621	+ 1·56197	+ 1·81307
0·2	+ 1·22140	+ 1·70996	+ 2·26367	+ 2·88772
0·3	+ 1·34986	+ 2·15977	+ 3·13167	+ 4·28499
0·4	+ 1·49182	+ 2·68528	+ 4·19700	+ 6·07789
0·5	+ 1·64872	+ 3·29744	+ 5·49574	+ 8·35352
0·6	+ 1·82212	+ 4·00866	+ 7·06982	+ 11·2155
0·7	+ 2·01375	+ 4·83301	+ 8·96791	+ 14·7869
0·8	+ 2·22554	+ 5·78641	+ 11·2464	+ 19·2132
0·9	+ 2·45960	+ 6·88689	+ 13·9705	+ 24·6669
1·0	+ 2·71828	+ 8·15485	+ 17·2158	+ 31·3509
1·2	+ 3·32012	+ 11·2884	+ 25·6313	+ 49·4087
1·4	+ 4·05520	+ 15·4098	+ 37·3619	+ 75·8463
1·6	+ 4·95303	+ 20·8027	+ 53·5588	+ 114·041
1·8	+ 6·04965	+ 27·8284	+ 75·7416	+ 168·606
2·0	+ 7·38906	+ 36·9453	+ 105·910	+ 245·809
2·2	+ 9·02501	+ 48·7351	+ 146·687	+ 354·132
2·4	+ 11·0232	+ 63·9344	+ 201·504	+ 505·003
2·6	+ 13·4637	+ 83·4752	+ 274·840	+ 713·765
2·8	+ 16·4446	+ 108·535	+ 372·526	+ 1000·95
3·0	+ 20·0855	+ 140·599	+ 502·138	+ 1393·94
3·5	+ 33·1155	+ 264·924	+ 1037·62	+ 3108·44
4·0	+ 54·5982	+ 491·383	+ 2092·93	+ 6722·85
4·5	+ 90·0171	+ 900·171	+ 4140·79	+ 14186·7
5·0	+ 148·413	+ 1632·54	+ 8063·78	+ 29336·3
5·5	+ 244·692	+ 2936·30	+ 15497·2	+ 59639·6
6·0	+ 403·429	+ 5244·57	+ 29450·3	+ 119496
6·5	+ 665·142	+ 9311·98	+ 55428·5	+ 236436
7·0	+1096·63	+16449·5	+103449	+ 462706
7·5	+1808·04	+28928·7	+191652	+ 896789
8·0	+2980·96	+50676·3	+352747	+1723192

M ($\alpha \, . \, \frac{1}{2} \, . \, x$)—cont.

x	$\alpha=-\frac{1}{2}$	$\alpha=-\frac{3}{2}$	$\alpha=-\frac{5}{2}$	$\alpha=-\frac{7}{2}$
0·0	+ 1·00000	+ 1·00000	+ 1·00000	+ 1·00000
0·1	+ 0·89830	+ 0·70503	+ 0·52483	+ 0·35717
0·2	+ 0·79306	+ 0·42027	+ 0·09866	− 0·17593
0·3	+ 0·68405	+ 0·14593	− 0·27955	− 0·60616
0·4	+ 0·57104	− 0·11777	− 0·61082	− 0·94026
0·5	+ 0·45376	− 0·37060	− 0·89622	− 1·18487
0·6	+ 0·33195	− 0·61230	− 1·13680	− 1·34653
0·7	+ 0·20530	− 0·84264	− 1·33367	− 1·43167
0·8	+ 0·07349	− 1·06133	− 1·48791	− 1·44662
0·9	− 0·06383	− 1·26810	− 1·60066	− 1·39759
1·0	− 0·20702	− 1·46265	− 1·67305	− 1·29070 :
1·2	− 0·51269	− 1·81386	− 1·70143	− 0·92716
1·4	− 0·84712	− 2·11231	− 1·58259	− 0·40261
1·6	− 1·21453	− 2·35506	− 1·32641	+ 0·23822
1·8	− 1·61983	− 2·53887	− 0·94317	+ 0·95249
2·0	− 2·06876	− 2·66015	− 0·44354	+ 1·69933
2·2	− 2·56803	− 2·71489	+ 0·16135	+ 2·43989
2·4	− 3·12551	− 2·69863	+ 0·85988	+ 3·13740
2·6	− 3·75041	− 2·60642	+ 1·63992	+ 3·75727
2·8	− 4·45358	− 2·43267	+ 2·48875	+ 4·26710
3·0	− 5·24774	− 2·17117	+ 3·39301	+ 4·63681
3·5	− 7·73625	− 1·08523	+ 5·80218	+ 4·77248
4·0	− 11·2124	+ 0·73183	+ 8·22631	+ 3·50330
4·5	− 16·1581	+ 3·46583	+10·3857	+ 0·57370
5·0	− 23·3084	+ 7·37289	+11·9516	− 4·15213
5·5	− 33·7890	+12·8099	+12·5319	−10·6749
6·0	− 49·3319	+20·2790	+11·6501	−18·8409
6·5	− 72·6130	+30·4942	+ 8·71849	−28·3180
7·0	−107·781	+44·4780	+ 2·99906	−38·5646
7·5	−161·288	+63·7081	− 6·45002	−48·7901
8·0	−243·202	+90·3340	−20·8501	−57·9033

M $(\alpha . \frac{1}{2} . x)$—cont.

x	$\alpha=1$	$\alpha=2$	$\alpha=3$	$\alpha=4$
0·0	+ 1·00000	+ 1·00000	+ 1·00000	+ 1·00000
0·1	+ 1·21388	+ 1·44221	+ 1·68557	+ 1·94455
0·2	+ 1·45786	+ 1·97835	+ 2·56656	+ 3·22784
0·3	+ 1·73572	+ 2·62430	+ 3·68438	+ 4·93621
0·4	+ 2·05174	+ 3·39831	+ 5·08790	+ 7·17427
0·5	+ 2·41069	+ 4·32137	+ 6·83473	+ 10·0683
0·6	+ 2·81790	+ 5·41759	+ 8·99263	+ 13·7704
0·7	+ 3·27935	+ 6·71458	+ 11·6411	+ 18·4628
0·8	+ 3·80175	+ 8·24402	+ 14·8733	+ 24·3640
0·9	+ 4·39256	+ 10·0421	+ 18·7983	+ 31·7346
1·0	+ 5·06016	+ 12·1504	+ 23·5433	+ 40·8851
1·2	+ 6·66425	+ 17·4935	+ 36·1115	+ 66·0710
1·4	+ 8·70287	+ 24·7383	+ 54·0818	+ 103·773
1·6	+ 11·2870	+ 34·4896	+ 79·4831	+ 159·369
1·8	+ 14·5548	+ 47·5309	+ 115·041	+ 240·324
2·0	+ 18·6789	+ 64·8761	+ 164·400	+ 356·937
2·2	+ 23·8738	+ 87·8331	+ 232·419	+ 523·348
2·4	+ 30·4068	+ 118·087	+ 325·550	+ 758·877
2·6	+ 38·6102	+ 157·802	+ 452·338	+ 1089·81
2·8	+ 48·8969	+ 209·757	+ 624·061	+ 1551·77
3·0	+ 61·7801	+ 277·510	+ 855·573	+ 2192·87
3·5	+ 109·914	+ 549·072	+ 1839·32	+ 5060·39
4·0	+ 193·640	+ 1064·52	+ 3846·72	+ 11294·2
4·5	+ 338·545	+ 2030·77	+ 7869·18	+ 24538·3
5·0	+ 588·290	+ 3823·38	+ 15808·2	+ 52142·4
5·5	+ 1017·20	+ 7119·91	+ 31276·7	+ 108748
6·0	+ 1751·60	+ 13136·5	+ 61084·6	+ 223211
6·5	+ 3005·76	+ 24045·6	+ 117974	+ 451857
7·0	+ 5142·69	+ 43712·4	+ 225633	+ 903710
7·5	+ 8776·41	+ 78987·2	+ 427847	+1788182
8·0	+14944·4	+141971	+ 805125	+3504751

M ($\alpha . \frac{1}{2} . x$)—*cont.*

x	$\alpha=-1$	$\alpha=-2$	$\alpha=-3$	$\alpha=-4$
0·0	+ 1·00000	+ 1·00000	+ 1·00000	+ 1·00000
0·1	+ 0·80000	+ 0·61333	+ 0·43947	+ 0·27788
0·2	+ 0·60000	+ 0·25333	− 0·04427	− 0·29682
0·3	+ 0·40000	− 0·08000	− 0·45440	− 0·73637
0·4	+ 0·20000	− 0·38667	− 0·79413	− 1·05263
0·5	+ 0·00000	− 0·66667	− 1·06667	− 1·25714
0·6	− 0·20000	− 0·92000	− 1·27520	− 1·36105
0·7	− 0·40000	− 1·14667	− 1·42293	− 1·35715
0·8	− 0·60000	− 1·34667	− 1·51307	− 1·30985
0·9	− 0·80000	− 1·52000	− 1·54880	− 1·17522
1·0	− 1·00000	− 1·66667	− 1·53333	− 0·98095
1·2	− 1·40000	− 1·88000	− 1·36160	− 0·45042
1·4	− 1·80000	− 1·98667	− 1·02347	+ 0·21152
1·6	− 2·20000	− 1·98667	− 0·54453	+ 0·94051
1·8	− 2·60000	− 1·88000	+ 0·04960	+ 1·67803
2·0	− 3·00000	− 1·66667	+ 0·73333	+ 2·37143
2·2	− 3·40000	− 1·34667	+ 1·48107	+ 2·97388
2·4	− 3·80000	− 0·92000	+ 2·26720	+ 3·44443
2·6	− 4·20000	− 0·38667	+ 3·06613	+ 3·74798
2·8	− 4·60000	+ 0·25333	+ 3·85227	+ 3·85525
3·0	− 5·00000	+ 1·00000	+ 4·60000	+ 3·74286
3·5	− 6·00000	+ 3·33333	+ 6·13333	+ 2·40000
4·0	− 7·00000	+ 6·33333	+ 6·86667	− 0·52381
4·5	− 8·00000	+10·0000	+ 6·40000	− 4·91429
5·0	− 9·00000	+14·3333	+ 4·33333	−10·4286
5·5	−10·0000	+19·3333	+ 0·26667	−16·4952
6·0	−11·0000	+25·0000	− 6·20000	−22·3143
6·5	−12·0000	+31·3333	−15·4667	−26·8571
7·0	−13·0000	+38·3333	−27·9333	−28·8667
7·5	−14·0000	+46·0000	−44·0000	−26·8571
8·0	−15·0000	+54·3333	−64·0667	−19·1143

$\mathbf{M}\,(\alpha\,.\,\frac{3}{2}\,.\,x)$

x	$\alpha=\frac{1}{2}$	$\alpha=\frac{3}{2}$	$\alpha=\frac{5}{2}$	$\alpha=\frac{7}{2}$
0·0	+ 1·00000	+ 1·00000	+ 1·00000	+ 1·00000
0·1	+ 1·03436	+ 1·10517	+ 1·17885	+ 1·25547
0·2	+ 1·07086	+ 1·22140	+ 1·38426	+ 1·56014
0·3	+ 1·10968	+ 1·34986	+ 1·61983	+ 1·92220
0·4	+ 1·15098	+ 1·49182	+ 1·88964	+ 2·35112
0·5	+ 1·19496	+ 1·64872	+ 2·19830	+ 2·85778
0·6	+ 1·24181	+ 1·82212	+ 2·55097	+ 3·45474
0·7	+ 1·29175	+ 2·01375	+ 2·95350	+ 4·15639
0·8	+ 1·34503	+ 2·22554	+ 3·41250	+ 4·97928
0·9	+ 1·40191	+ 2·45960	+ 3·93536	+ 5·94240
1·0	+ 1·46265	+ 2·71828	+ 4·53047	+ 7·06753
1·2	+ 1·59700	+ 3·32012	+ 5·97621	+ 9·90723
1·4	+ 1·75083	+ 4·05520	+ 7·84005	+ 13·7444
1·6	+ 1·92736	+ 4·95303	+ 10·2363	+ 18·9008
1·8	+ 2·13041	+ 6·04965	+ 13·3092	+ 25·7957
2·0	+ 2·36445	+ 7·38906	+ 17·2411	+ 34·9749
2·2	+ 2·63478	+ 9·02501	+ 22·2617	+ 47·1467
2·4	+ 2·94764	+ 11·0232	+ 28·6603	+ 63·2289
2·6	+ 3·31041	+ 13·4637	+ 36·8009	+ 84·4087
2·8	+ 3·73183	+ 16·4446	+ 47·1413	+ 112·218
3·0	+ 4·22221	+ 20·0855	+ 60·2566	+ 148·633
3·5	+ 5·83596	+ 33·1155	+ 110·385	+ 295·831
4·0	+ 8·22631	+ 54·5982	+ 200·193	+ 578·740
4·5	+ 11·7973	+ 90·0171	+ 360·069	+ 1116·21
5·0	+ 17·1722	+ 148·413	+ 643·124	+ 2127·26
5·5	+ 25·3164	+ 244·692	+ 1141·90	+ 4012·95
6·0	+ 37·7301	+ 403·429	+ 2017·14	+ 7503·78
6·5	+ 56·7504	+ 665·142	+ 3547·42	+13923·6
7·0	+ 86·0296	+1096·63	+ 6214·25	+25661·2
7·5	+131·289	+1808·04	+10848·3	+47009·1
8·0	+201·510	+2980·96	+18879·4	+85652·9

$M(\alpha . \frac{3}{2} . x)$—cont.

x	$\alpha=-\frac{1}{2}$	$\alpha=-\frac{3}{2}$	$\alpha=-\frac{5}{2}$	$\alpha=-\frac{7}{2}$
0·0	+ 1·00000	+ 1·00000	+ 1·00000	+ 1·00000
0·1	+ 0·96633	+ 0·90100	+ 0·83831	+ 0·77817
0·2	+ 0·93196	+ 0·80404	+ 0·68648	+ 0·57867
0·3	+ 0·89687	+ 0·70913	+ 0·54435	+ 0·40054
0·4	+ 0·86101	+ 0·61632	+ 0·41179	+ 0·24279
0·5	+ 0·82436	+ 0·52562	+ 0·28865	+ 0·10446
0·6	+ 0·78688	+ 0·43708	+ 0·17477	− 0·01539
0·7	+ 0·74853	+ 0·35074	+ 0·07000	− 0·11771
0·8	+ 0·70926	+ 0·26661	− 0·02581	− 0·20341
0·9	+ 0·66904	+ 0·18475	− 0·11281	− 0·27341
1·0	+ 0·62782	+ 0·10520	− 0·19118	− 0·32862
1·2	+ 0·54216	− 0·04685	− 0·32261	− 0·39818
1·4	+ 0·45185	− 0·18919	− 0·42142	− 0·41907
1·6	+ 0·35642	− 0·32145	− 0·48895	− 0·39805
1·8	+ 0·25529	− 0·44325	− 0·52657	− 0·34169
2·0	+ 0·14785	− 0·55415	− 0·53572	− 0·25634
2·2	+ 0·03338	− 0·65369	− 0·51785	− 0·14813
2·4	− 0·08893	− 0·74136	− 0·47448	− 0·02300
2·6	− 0·22000	− 0·81660	− 0·40718	+ 0·11337
2·8	− 0·36088	− 0·87883	− 0·31756	+ 0·25552
3·0	− 0·51276	− 0·92736	− 0·20730	+ 0·39821
3·5	− 0·95014	− 0·98392	+ 0·14710	+ 0·72527
4·0	− 1·49302	− 0·93681	+ 0·59038	+ 0·95449
4·5	− 2·18044	− 0·76887	+ 1·09022	+ 1·02566
5·0	− 3·06813	− 0·45788	+ 1·61038	+ 0·89006
5·5	− 4·23626	+ 0·02527	+ 2·10970	+ 0·51163
6·0	− 5·80091	+ 0·71908	+ 2·54092	+ 0·13181
6·5	− 7·93132	+ 1·67505	+ 2·84896	− 1·04691
7·0	− 10·8756	+ 2·96278	+ 2·96883	− 2·22284
7·5	− 14·9998	+ 4·67721	+ 2·82267	− 3·62892
8·0	− 20·8460	+ 6·94901	+ 2·31583	− 5·21156

$M(\alpha \,.\, \frac{3}{2} \,.\, x)$—cont.

x	$\alpha=1$	$\alpha=2$	$\alpha=3$	$\alpha=4$
0·0	+ 1·00000	+ 1·00000	+ 1·00000	+ 1·00000
0·1	+ 1·06941	+ 1·14165	+ 1·21679	+ 1·29492
0·2	+ 1·14464	+ 1·30125	+ 1·47052	+ 1·65320
0·3	+ 1·22620	+ 1·48096	+ 1·76680	+ 2·08639
0·4	+ 1·31468	+ 1·68321	+ 2·11198	+ 2·60797
0·5	+ 1·41069	+ 1·91069	+ 2·51336	+ 3·23359
0·6	+ 1·51491	+ 2·16641	+ 2·97920	+ 3·98144
0·7	+ 1·62811	+ 2·45373	+ 3·51894	+ 4·87264
0·8	+ 1·75109	+ 2·77642	+ 4·14332	+ 5·93165
0·9	+ 1·88475	+ 3·13866	+ 4·86453	+ 7·18682
1·0	+ 2·03008	+ 3·54512	+ 5·69644	+ 8·67091
1·2	+ 2·36010	+ 4·51217	+ 7·75750	+ 12·4832
1·4	+ 2·75103	+ 5·72695	+ 10·4798	+ 17·7468
1·6	+ 3·21467	+ 7·25081	+ 14·0605	+ 24·9643
1·8	+ 3·76523	+ 9·16002	+ 18·7527	+ 34·8008
2·0	+ 4·41972	+ 11·5493	+ 24·8810	+ 48·1342
2·2	+ 5·19860	+ 14·5362	+ 32·8604	+ 66·1202
2·4	+ 6·12642	+ 18·2666	+ 43·2216	+ 90·2764
2·6	+ 7·23273	+ 22·9215	+ 56·6415	+ 122·591
2·8	+ 8·55302	+ 28·7250	+ 73·9829	+ 165·663
3·0	+ 10·1300	+ 35·9550	+ 96·3439	+ 222·882
3·5	+ 15·5592	+ 62·7368	+ 184·321	+ 460·153
4·0	+ 24·0800	+ 108·860	+ 347·775	+ 930·933
4·5	+ 37·5051	+ 188·025	+ 648·712	+ 1852·12
5·0	+ 58·7290	+ 323·509	+ 1198·48	+ 3633·42
5·5	+ 92·3820	+ 554·792	+ 2196·07	+ 7042·85
6·0	+145·883	+ 948·740	+ 3995·68	+ 13510·5
6·5	+231·213	+1618·45	+ 7225·24	+ 25683·3
7·0	+367·264	+2754·98	+12994·3	+ 48434·1
7·5	+585·027	+4680·72	+23257·3	+ 90689·0
8·0	+933·960	+7939·16	+41447·1	+168727

$M(\alpha \cdot \frac{3}{2} \cdot x)$—cont.

x	$\alpha=-1$	$\alpha=-2$	$\alpha=-3$	$\alpha=-4$
0·0	+1·00000	+1·00000	+1·00000	+1·00000
0·1	+0·93333	+0·86933	+0·80792	+0·74903
0·2	+0·86667	+0·74400	+0·63139	+0·52826
0·3	+0·80000	+0·62400	+0·46994	+0·33591
0·4	+0·73333	+0·50933	+0·32312	+0·17026
0·5	+0·66667	+0·40000	+0·19048	+0·02963
0·6	+0·60000	+0·29600	+0·07154	−0·08763
0·7	+0·53333	+0·19733	−0·03413	−0·18313
0·8	+0·46667	+0·10400	−0·12701	−0·25844
0·9	+0·40000	+0·01600	−0·20754	−0·31506
1·0	+0·33333	−0·06667	−0·27619	−0·35450
1·2	+0·20000	−0·21600	−0·37966	−0·38752
1·4	+0·06667	−0·34400	−0·44107	−0·36856
1·6	−0·06667	−0·45067	−0·46408	−0·30801
1·8	−0·20000	−0·53600	−0·45234	−0·21563
2·0	−0·33333	−0·60000	−0·40952	−0·10053
2·2	−0·46667	−0·64267	−0·33928	+0·02885
2·4	−0·60000	−0·66400	−0·24526	+0·16471
2·6	−0·73333	−0·66400	−0·13112	+0·29989
2·8	−0·86667	−0·64267	−0·00053	+0·42789
3·0	−1·00000	−0·60000	+0·14286	+0·54286
3·5	−1·33333	−0·40000	+0·53333	+0·74074
4·0	−1·66667	−0·06667	+0·92381	+0·76296
4·5	−2·00000	+0·40000	+1·25714	+0·57143
5·0	−2·33333	+1·00000	+1·47619	+0·15344
5·5	−2·66667	+1·73333	+1·52381	−0·47831
6·0	−3·00000	+2·60000	+1·34286	−1·28571
6·5	−3·33333	+3·60000	+0·87619	−2·20529
7·0	−3·66667	+4·73333	+0·06667	−3·14815
7·5	−4·00000	+6·00000	−1·14286	−4·00000
8·0	−4·33333	+7·40000	−2·80952	−4·62116

$\mathbf{M}(\alpha \,.\, -\tfrac{1}{2} \,.\, x)$

x	$\alpha=\frac{1}{2}$	$\alpha=\frac{3}{2}$	$\alpha=\frac{5}{2}$	$\alpha=\frac{7}{2}$
0·0	+ 1·00000	+ 1·00000	+ 1·00000	+ 1·00000
0·1	+ 0·88414	+ 0·61890	+ 0·30650	— 0·05611
0·2	+ 0·73284	+ 0·04886	— 0·85661	— 2·01170
0·3	+ 0·53994	— 0·75592	— 2·63492	— 5·20592
0·4	+ 0·29836	— 1·84986	— 5·20746	— 10·0698
0·5	+ 0·00000	— 3·29744	— 8·79318	— 17·1467
0·6	— 0·36442	— 5·17482	— 13·6586	— 27·1172
0·7	— 0·80550	— 7·57171	— 20·1268	— 40·8284
0·8	— 1·33532	— 10·5936	— 28·5878	— 59·3290
0·9	— 1·96768	— 14·3641	— 39·5111	— 83·9114
1·0	— 2·71828	— 19·0280	— 53·4595	— 116·161
1·2	— 4·64816	— 31·7403	— 93·2554	— 211·836
1·4	— 7·29936	— 50·4467	— 155·060	— 367·430
1·6	— 10·8967	— 77·4654	— 248·854	— 613·786
1·8	— 15·7291	— 115·911	— 388·581	— 995·563
2·0	— 22·1672	— 169·948	— 593·588	— 1576·82
2·2	— 30·6850	— 245·119	— 890·540	— 2448·72
2·4	— 41·8881	— 348·773	— 1315·99	— 3740·00
2·6	— 56·5477	— 490·619	— 1919·79	— 5631·36
2·8	— 75·6454	— 683·440	— 2769·59	— 8374·90
3·0	— 100·428	— 944·020	— 3956·85	— 12320·5
3·5	— 198·693	— 2053·16	— 9316·48	— 31075·5
4·0	— 382·187	— 4313·25	— 21056·7	— 74839·5
4·5	— 720·137	— 8821·68	— 46088·8	— 173769
5·0	—1335·72	—17661·2	— 98299·0	— 391662
5·5	—2446·92	—34746·3	—205215	— 861250
6·0	—4437·72	—67372·6	—420776	—1854724

M(α. − ½ . x)—cont.

x	$\alpha=-\frac{1}{2}$	$\alpha=-\frac{3}{2}$	$\alpha=-\frac{5}{2}$	$\alpha=-\frac{7}{2}$
0·0	+ 1·00000	+ 1·00000	+ 1·00000	+ 1·00000
0·1	+ 1·10517	+ 1·28483	+ 1·42584	+ 1·53080
0·2	+ 1·22140	+ 1·53863	+ 1·70673	+ 1·74620
0·3	+ 1·34986	+ 1·76029	+ 1·84785	+ 1·68012
0·4	+ 1·49182	+ 1·94865	+ 1·85444	+ 1·36578
0·5	+ 1·64872	+ 2·10248	+ 1·73189	+ 0·83567
0·6	+ 1·82212	+ 2·22046	+ 1·48569	+ 0·12153
0·7	+ 2·01375	+ 2·30117	+ 1·12148	− 0·74565
0·8	+ 2·22554	+ 2·34312	+ 0·64500	− 1·73566
0·9	+ 2·45960	+ 2·34471	+ 0·06214	− 2·81904
1·0	+ 2·71828	+ 2·30424	− 0·62106	− 3·96716
1·2	+ 3·32012	+ 2·08967	− 2·26361	− 6·34704
1·4	+ 4·05520	+ 1·68326	− 4·23121	− 8·66245
1·6	+ 4·95303	+ 1·06653	− 6·46967	− 10·7142
1·8	+ 6·04965	+ 0·21826	− 8·92169	− 12·3171
2·0	+ 7·38906	− 0·88598	−11·5266	− 13·3007
2·2	+ 9·02501	− 2·27432	−14·2198	− 13·5099
2·4	+ 11·0232	− 3·97925	−16·9327	− 12·8053
2·6	+ 13·4637	− 6·03840	−19·5918	− 11·0642
2·8	+ 16·4446	− 8·49538	−22·1184	− 8·18138
3·0	+ 20·0855	− 11·4009	−24·4279	− 4·06981
3·5	+ 33·1155	− 21·0383	−28·6349	+ 11·9804
4·0	+ 54·5982	− 35·1007	−29·2461	+ 36·5644
4·5	+ 90·0171	− 55·4061	−24·2136	+ 69·2576
5·0	+148·413	− 84·6710	−10·9422	+108·574
5·5	+244·692	−126·987	+13·9218	+151·772
6·0	+403·429	−188·554	+54·7948	+194·596

$M(\alpha \,.\, -\tfrac{1}{2} \,.\, x)$—cont.

x	$\alpha=1$	$\alpha=2$	$\alpha=3$	$\alpha=4$
0·0	+ 1·00000	+ 1·00000	+ 1·00000	+ 1·00000
0·1	+ 0·75722	+ 0·46878	+ 0·13167	— 0·25724
0·2	+ 0·41686	— 0·37448	— 1·40111	— 2·69225
0·3	— 0·04143	— 1·61601	— 3·82664	— 6·78836
0·4	— 0·64139	— 3·36004	— 7·43036	— 13·1698
0·5	— 1·41069	— 5·73206	— 12·5668	— 22·6351
0·6	— 2·38148	— 8·88258	— 19·6737	— 36·1982
0·7	— 3·59110	— 12·9915	— 29·2891	— 55·1370
0·8	— 5·08280	— 18·2732	— 42·0706	— 81·0529
0·9	— 6·90660	— 24·9825	— 58·8194	— 115·942
1·0	— 9·12031	— 33·4211	— 80·5076	— 162·278
1·2	— 14·9942	— 56·9785	— 143·646	— 302·216
1·4	— 23·3680	— 92·6354	— 244·064	— 534·628
1·6	— 35·1182	— 145·485	— 399·831	— 909·811
1·8	— 51·3974	— 222·509	— 636·655	— 1501·82
2·0	— 73·7155	— 333·220	— 990·820	— 2418·57
2·2	— 104·045	— 490·511	— 1513·15	— 3815·89
2·4	— 144·953	— 711·768	— 2274·41	— 5917·02
2·6	— 199·773	— 1020·34	— 3372·50	— 9039·51
2·8	— 272·823	— 1447·46	— 4942·20	— 13632·1
3·0	— 369·680	— 2034·74	— 7168·18	— 20325·4
3·5	— 768·401	— 4611·90	— 17487·1	— 52909·8
4·0	— 1548·12	— 10064·3	— 40838·1	— 131192
4·5	— 3045·91	— 21322·9	— 92145·5	— 312990
5·0	— 5881·90	— 44115·7	—202197	— 723621
5·5	—11188·2	— 89507·3	—433551	—1629779
6·0	—21018·2	—178656	—911671	—3590197

$M(\alpha . -\frac{1}{2} . x)$—cont.

x	$\alpha=-1$	$\alpha=-2$	$\alpha=-3$	$\alpha=-4$
0·0	+ 1·00000	+ 1·00000	+ 1·00000	+ 1·00000
0·1	+ 1·20000	+ 1·36000	+ 1·48267	+ 1·57056
0·2	+ 1·40000	+ 1·64000	+ 1·74133	+ 1·72363
0·3	+ 1·60000	+ 1·84000	+ 1·79200	+ 1·51936
0·4	+ 1·80000	+ 1·96000	+ 1·65067	+ 1·01536
0·5	+ 2·00000	+ 2·00000	+ 1·33333	+ 0·26667
0·6	+ 2·20000	+ 1·96000	+ 0·85600	− 0·67424
0·7	+ 2·40000	+ 1·84000	+ 0·23467	− 1·75744
0·8	+ 2·60000	+ 1·64000	− 0·51467	− 2·93557
0·9	+ 2·80000	+ 1·36000	− 1·37600	− 4·16384
1·0	+ 3·00000	+ 1·00000	− 2·33333	− 5·40000
1·2	+ 3·40000	+ 0·04000	− 4·47200	− 7·73984
1·4	+ 3·80000	− 1·24000	− 6·80267	− 9·66837
1·6	+ 4·20000	− 2·84000	− 9·19733	− 10·9398
1·8	+ 4·60000	− 4·76000	− 11·5280	− 11·3494
2·0	+ 5·00000	− 7·00000	− 13·6667	− 10·7333
2·2	+ 5·40000	− 9·56000	− 15·4853	− 8·96864
2·4	+ 5·80000	− 12·4400	− 16·8560	− 5·97344
2·6	+ 6·20000	− 15·6400	− 17·6507	− 1·70677
2·8	+ 6·60000	− 19·1600	− 17·7413	+ 3·83136
3·0	+ 7·00000	− 23·0000	− 17·0000	+ 10·6000
3·5	+ 8·00000	− 34·0000	− 10·6667	+ 32·2667
4·0	+ 9·00000	− 47·0000	+ 3·66667	+ 58·6000
4·5	+10·0000	− 62·0000	+ 28·0000	+ 85·6000
5·0	+11·0000	− 79·0000	+ 64·3333	+107·667
5·5	+12·0000	− 98·0000	+114·667	+117·600
6·0	+13·0000	−119·000	+181·000	+106·600
6·5	+14·0000	−142·000	+265·333	+ 64·2667
7·0	+15·0000	−167·000	+369·667	+ 21·4000
7·5	+16·0000	−194·000	+496·000	−164·000
8·0	+17·0000	−223·000	+646·333	−378·733

M $(\alpha \,.\, -\tfrac{3}{2} \,.\, x)$

x	$\alpha=\frac{1}{2}$	$\alpha=\frac{3}{2}$	$\alpha=\frac{5}{2}$	$\alpha=\frac{7}{2}$
0·0	+ 1·00000	+ 1·00000	+ 1·00000	+ 1·00000
0·1	+ 0·97255	+ 0·93129	+ 0·91086	+ 0·91460
0·2	+ 0·96084	+ 0·95432	+ 1·06854	+ 1·33676
0·3	+ 0·97190	+ 1·12308	+ 1·65007	+ 2·69125
0·4	+ 1·01444	+ 1·50774	+ 2·89639	+ 5·58167
0·5	+ 1·09915	+ 2·19830	+ 5·12936	+ 10·8449
0·6	+ 1·23904	+ 3·30897	+ 8·77241	+ 19·6193
0·7	+ 1·44990	+ 4·98337	+ 14·3759	+ 33·4291
0·8	+ 1·75076	+ 7·40067	+ 22·6475	+ 54·2896
0·9	+ 2·16445	+ 10·7829	+ 34·4895	+ 84·8364
1·0	+ 2·71828	+ 15·4036	+ 51·0433	+ 128·484
1·2	+ 4·38255	+ 29·7748	+ 104·379	+ 273·848
1·4	+ 7·08308	+ 54·1667	+ 198·889	+ 541·824
1·6	+ 11·2929	+ 93·9227	+ 359·366	+ 1014·07
1·8	+ 17·6650	+ 156·758	+ 623·056	+ 1817·73
2·0	+ 27·0932	+ 253·691	+ 1045·14	+ 3147·57
2·2	+ 40·7931	+ 400·301	+ 1706·43	+ 5297·88
2·4	+ 60·4070	+ 618·444	+ 2724·03	+ 8708·03
2·6	+ 88·1426	+ 938·548	+ 4266·18	+ 14027·2
2·8	+ 126·953	+ 1402·71	+ 6572·60	+ 22205·7
3·0	+ 180·770	+ 2068·81	+ 9982·51	+ 34623·4
3·5	+ 419·462	+ 5210·16	+ 26948·6	+ 99458·2
4·0	+ 928·169	+ 12430·2	+ 68581·3	+ 268153
4·5	+ 1980·38	+ 28445·4	+ 166712	+ 688019
5·0	+ 4106·10	+ 62976·7	+ 390640	+1696181
5·5	+ 8319·53	+135722	+ 888177	+4046095
6·0	+16540·6	+286031	+1969136	+9388030

$M(\alpha \,.\, -\tfrac{3}{2} \,.\, x)$—cont.

x	$\alpha = -\frac{1}{2}$	$\alpha = -\frac{3}{2}$	$\alpha = -\frac{5}{2}$	$\alpha = -\frac{7}{2}$
0·0	+ 1·00000	+ 1·00000	+ 1·00000	+ 1·00000
0·1	+ 1·03149	+ 1·10517	+ 1·19083	+ 1·28588
0·2	+ 1·05855	+ 1·22140	+ 1·42655	+ 1·65412
0·3	+ 1·07989	+ 1·34986	+ 1·70192	+ 2·07149
0·4	+ 1·09400	+ 1·49182	+ 2·01147	+ 2·50598
0·5	+ 1·09915	+ 1·64872	+ 2·34955	+ 2·92685
0·6	+ 1·09327	+ 1·82212	+ 2·71030	+ 3·30458
0·7	+ 1·07400	+ 2·01375	+ 3·08763	+ 3·61099
0·8	+ 1·03859	+ 2·22554	+ 3·47521	+ 3·81920
0·9	+ 0·98384	+ 2·45960	+ 3·86643	+ 3·90371
1·0	+ 0·90609	+ 2·71828	+ 4·25444	+ 3·84040
1·2	+ 0·66402	+ 3·32012	+ 4·99185	+ 3·18097
1·4	+ 0·27035	+ 4·05520	+ 5·62625	+ 1·67712
1·6	— 0·33020	+ 4·95303	+ 6·09067	— 0·81031
1·8	— 1·20993	+ 6·04965	+ 6·31155	— 4·39448
2·0	— 2·46302	+ 7·38906	+ 6·20775	— 9·16102
2·2	— 4·21167	+ 9·02501	+ 5·68935	— 15·1664
2·4	— 6·61391	+ 11·0232	+ 4·65638	— 22·4359
2·6	— 9·87341	+ 13·4637	+ 2·99718	— 30·9619
2·8	— 14·2520	+ 16·4446	+ 0·58660	— 40·7010
3·0	— 20·0855	+ 20·0855	— 2·71621	— 51·5719
3·5	— 44·1539	+ 33·1155	— 15·9738	— 82·7886
4·0	— 90·9969	+ 54·5982	— 39·0038	—116·993
4·5	— 180·034	+ 90·0171	— 76·2011	—148·842
5·0	— 346·297	+148·413	—133·824	—170·297
5·5	— 652·512	+244·692	—220·925	—169·879
6·0	—1210·29	+403·429	—350·786	—127·607

M(α. − $\frac{3}{2}$.x)—cont.

x	$\alpha = 1$	$\alpha = 2$	$\alpha = 3$	$\alpha = 4$
0·0	+ 1·00000	+ 1·00000	+ 1·00000	+ 1·00000
0·1	+ 0·94952	+ 0·91827	+ 0·90949	+ 0·92664
0·2	+ 0·94442	+ 0·99435	+ 1·18116	+ 1·54013
0·3	+ 1·00829	+ 1·33149	+ 2·09682	+ 3·45449
0·4	+ 1·17104	+ 2·06705	+ 4·04848	+ 7·56042
0·5	+ 1·47023	+ 3·38091	+ 7·56984	+ 15·1149
0·6	+ 1·95259	+ 5·50562	+ 13·3751	+ 27·8544
0·7	+ 2·67585	+ 8·73855	+ 22·4068	+ 48·1374
0·8	+ 3·71082	+ 13·4565	+ 35·8942	+ 79·1224
0·9	+ 5·14396	+ 20·1334	+ 55·4251	+ 124·990
1·0	+ 7·08021	+ 29·3609	+ 83·0327	+ 191·218
1·2	+ 12·9954	+ 58·5782	+ 174·495	+ 415·268
1·4	+ 22·8102	+ 109·270	+ 337·063	+ 836·049
1·6	+ 38·4595	+ 193·643	+ 620·130	+ 1590·59
1·8	+ 62·6768	+ 329·687	+ 1093·67	+ 2895·86
2·0	+ 99·2874	+ 543·580	+ 1864·67	+ 5089·43
2·2	+ 153·599	+ 873·015	+ 3092·31	+ 8688·94
2·4	+ 232·924	+ 1371·75	+ 5010·81	+ 14478·0
2·6	+ 347·273	+ 2115·87	+ 7961·53	+ 23630·0
2·8	+ 510·269	+ 3212·19	+ 12437·6	+ 37884·3
3·0	+ 740·361	+ 4809·85	+ 19146·2	+ 59797·0
3·5	+ 1793·93	+ 12555·0	+ 53358·3	+ 176815
4·0	+ 4129·32	+ 30967·4	+ 139869	+ 489713
4·5	+ 9138·73	+ 73107·3	+ 349544	+1288514
5·0	+19607·3	+166660	+ 840651	+3252722
5·5	+41024·5	+369218	+1958905	+7934763

$M(\alpha \,.\, -\tfrac{3}{2} \,.\, x)$—cont.

x	$\alpha = -1$	$\alpha = -2$	$\alpha = -3$	$\alpha = -4$
0·0	+1·00000	+ 1·00000	+ 1·00000	+ 1·00000
0·1	+1·06667	+ 1·14667	+ 1·23733	+ 1·33618
0·2	+1·13333	+ 1·32000	+ 1·53867	+ 1·77084
0·3	+1·20000	+ 1·52000	+ 1·88800	+ 2·24640
0·4	+1·26667	+ 1·74667	+ 2·26933	+ 2·70951
0·5	+1·33333	+ 2·00000	+ 2·66667	+ 3·11111
0·6	+1·40000	+ 2·28000	+ 3·06400	+ 3·40640
0·7	+1·46667	+ 2·58667	+ 3·44533	+ 3·55484
0·8	+1·53333	+ 2·92000	+ 3·79467	+ 3·52018
0·9	+1·60000	+ 3·28000	+ 4·09600	+ 3·27040
1·0	+1·66667	+ 3·66667	+ 4·33333	+ 2·77778
1·2	+1·80000	+ 4·52000	+ 4·55200	+ 0·97440
1·4	+1·93333	+ 5·48000	+ 4·32267	— 2·02649
1·6	+2·06667	+ 6·54667	+ 3·51733	— 6·29316
1·8	+2·20000	+ 7·72000	+ 2·00800	— 11·8256
2·0	+2·33333	+ 9·00000	— 0·33333	— 18·5556
2·2	+2·46667	+10·3867	— 3·63467	— 26·3465
2·4	+2·60000	+11·8800	— 8·02400	— 34·9936
2·6	+2·73333	+13·4800	— 13·6293	— 44·2238
2·8	+2·86667	+15·1867	— 20·5787	— 53·6958
3·0	+3·00000	+17·0000	— 29·0000	— 63·0000
3·5	+3·33333	+22·0000	— 57·3333	— 82·2222
4·0	+3·66667	+27·6667	— 97·6667	— 87·8889
4·5	+4·00000	+34·0000	— 152·000	— 68·0000
5·0	+4·33333	+41·0000	— 222·333	— 7·88889
5·5	+4·66667	+48·6667	— 310·667	+ 109·778
6·0	+5·00000	+57·0000	— 419·000	+ 305·000
6·5	+5·33333	+66·0000	— 549·333	+ 600·444
7·0	+5·66667	+75·6667	— 703·667	+1021·44
7·5	+6·00000	+86·0000	— 884·000	+1596·00
8·0	+6·33333	+97·0000	—1092·33	+2354·78

Hyperbolic Sines and Cosines, Sinh x and Cosh x.

The exponential and other functions were calculated by Bretschneider* to twenty places of decimals for the first ten integer values of x. Tables of the first hundred multiples of $e^{0\cdot1}$ and $e^{-0\cdot1}$ were constructed to the same number of places to find intermediate values of both e^x and e^{-x}: the results were checked by comparing the values of, say, $e^{7\cdot5}$ obtained from $e^{7\cdot0}$ and $e^{8\cdot0}$. The calculations were carried to eighteen or more decimals: fifteen places are given in the following tables of sinh x and cosh x.

x	Sinh x	x	Sinh x
0·1	0·10016 67500 19844	5·1	82·00790 52766 68114
0·2	0·20133 60025 41094	5·2	90·63336 26553 65209
0·3	0·30452 02934 47143	5·3	100·16590 91904 42387
0·4	0·41075 23258 02816	5·4	110·70094 98116 22237
0·5	0·52109 53054 93747	5·5	122·34392 27463 90962
0·6	0·63665 35821 48241	5·6	135·21135 47812 18073
0·7	0·75858 37018 39534	5·7	149·43202 75008 01381
0·8	0·88810 59821 87623	5·8	165·14826 61774 51639
0·9	1·02651 67257 08175	5·9	182·51736 42102 55004
1·0	1·17520 11936 43801	6·0	201·71315 73702 79228
1·1	1·33564 74701 24177	6·1	222·92776 36073 98723
1·2	1·50946 13554 12173	6·2	246·37350 58313 09979
1·3	1·69838 24372 92616	6·3	272·28503 69105 76002
1·4	1·90430 15014 51534	6·4	300·92168 81574 04441
1·5	2·12927 94550 94817	6·5	332·57006 48025 84432
1·6	2·37556 79532 00230	6·6	367·54691 44369 67674
1·7	2·64563 19338 37233	6·7	406·20229 71278 20220
1·8	2·94217 42880 95680	6·8	448·92308 89376 34926
1·9	3·26816 29115 28317	6·9	496·13685 39097 98414
2·0	3·62686 04078 47019	7·0	548·31612 32732 46522
2·1	4·02185 67421 57334	7·1	605·98312 46938 26728
2·2	4·45710 51705 35894	7·2	669·71500 89043 04727
2·3	4·93696 18055 45959	7·3	740·14962 60228 85014
2·4	5·46622 92136 76095	7·4	817·99190 93715 82705
2·5	6·05020 44810 39787	7·5	904·02093 06858 46530
2·6	6·69473 22283 93678	7·6	999·09769 73263 42259
2·7	7·40626 31060 66542	7·7	1104·17376 95300 12819
2·8	8·19191 83542 35916	7·8	1220·30078 39447 60049
2·9	9·05956 10746 93327	7·9	1348·64097 87624 84194
3·0	10·01787 49274 09902	8·0	1490·47882 57895 50186
3·1	11·07645 10395 24038	8·1	1647·23388 58723 51627
3·2	12·24588 39965 65491	8·2	1820·47501 63393 92375
3·3	13·53787 78766 28324	8·3	2011·93607 26527 41367
3·4	14·96536 33887 18344	8·4	2223·53326 14162 65953
3·5	16·54262 72876 34998	8·5	2457·38431 84153 82682
3·6	18·28545 53606 15348	8·6	2715·82970 36285 93327
3·7	20·21129 04167 98526	8·7	3001·45602 53376 05496
3·8	22·33940 68607 22329	8·8	3317·12192 77724 05032
3·9	24·69110 35970 42185	8·9	3665·98670 13835 33212
4·0	27·28991 71971 27752	9·0	4051·54190 20827 89961
4·1	30·16185 74609 80104	9·1	4477·64629 59083 51610
4·2	33·33566 77320 52332	9·2	4948·56447 88522 57025
4·3	36·84311 25702 91798	9·3	5469·00955 83704 76138
4·4	40·71929 56625 32525	9·4	6044·19032 37464 59420
4·5	45·00301 11519 91786	9·5	6679·86337 74050 21194
4·6	49·73713 19030 94588	9·6	7382·39074 89242 68062
4·7	54·96903 85875 10902	9·7	8158·80356 83659 68590
4·8	60·75109 38858 42930	9·8	9016·87243 61884 55907
4·9	67·14116 65509 32280	9·9	9965·18519 40278 03717
5·0	74·20321 05777 88759	10·0	11013·23287 47033 93377

* C. A. Bretschneider. *Archiv der Math. u. Phys.*, Band 3, 1843, s. 28-34.

x	Cosh x			x	Cosh x		
0·1	1·00500	41680	55804	5·1	82·01400	20232	33630
0·2	1·02006	67556	19076	5·2	90·63887	92197	85970
0·3	1·04533	85141	28860	5·3	100·17090	07843	49298
0·4	1·08107	23718	38455	5·4	110·70546	63925	64850
0·5	1·12762	59652	06381	5·5	122·34800	95178	29426
0·6	1·18546	52182	42268	5·6	135·21505	26449	34556
0·7	1·25516	90056	30943	5·7	149·43537	34662	58852
0·8	1·33743	49463	04845	5·8	165·15129	37321	97015
0·9	1·43308	63854	48774	5·9	182·52010	36550	73773
1·0	1·54308	06348	15244	6·0	201·71563	61224	55894
1·1	1·66851	85538	22256	6·1	222·93000	64751	18209
1·2	1·81065	55673	24375	6·2	246·37553	52619	46275
1·3	1·97091	42303	26628	6·3	272·28687	32153	53031
1·4	2·15089	84653	93141	6·4	300·92334	97146	77615
1·5	2·35240	96152	43247	6·5	332·57156	82417	77409
1·6	2·57746	44711	94885	6·6	367·54827	48050	05221
1·7	2·82831	54578	89967	6·7	406·20352	80397	22893
1·8	3·10747	31763	17266	6·8	448·92420	27127	82771
1·9	3·41773	15307	50952	6·9	496·13786	16952	27463
2·0	3·76219	56910	83631	7·0	548·31703	51552	12077
2·1	4·14431	31704	10316	7·1	605·98394	97987	49994
2·2	4·56790	83288	98227	7·2	669·71575	54901	13103
2·3	5·03722	06492	68762	7·3	740·15030	15616	60208
2·4	5·55694	71669	65507	7·4	817·99252	06243	43835
2·5	6·13228	94796	63686	7·5	904·02148	37702	16677
2·6	6·76900	58066	08012	7·6	999·09819	77777	75700
2·7	7·47346	86188	06292	7·7	1104·17422	23571	95705
2·8	8·25272	84168	61134	7·8	1220·30119	36797	39029
2·9	9·11458	42947	49734	7·9	1348·64134	95060	24653
3·0	10·06766	19957	77766	8·0	1490·47916	12521	78089
3·1	11·12150	02419	17596	8·1	1647·23418	94114	89706
3·2	12·28664	62005	43857	8·2	1820·47529	09929	62347
3·3	13·57476	10440	29564	8·3	2011·93632	11695	68475
3·4	14·99873	66586	78670	8·4	2223·53348	62835	90132
3·5	16·57282	46710	57316	8·5	2457·38452	18837	51693
3·6	18·31277	90830	62640	8·6	2715·82988	77343	86995
3·7	20·23601	39432	68865	8·7	3001·45619	19234	16484
3·8	22·36177	76325	78494	8·8	3317·12207	85054	80127
3·9	24·71134	55084	87989	8·9	3665·98683	77724	59694
4·0	27·30823	28360	16487	9·0	4051·54202	54925	94047
4·1	30·17843	01363	81865	9·1	4477·64640	75741	60100
4·2	33·35066	33088	72810	9·2	4948·56457	98916	58862
4·3	36·85668	11293	03999	9·3	5469·00964	97947	07616
4·4	40·73157	30024	35593	9·4	6044·19040	64705	24977
4·5	45·01412	01485	30028	9·5	6679·86345	22568	51082
4·6	49·74718	37388	39221	9·6	7382·39081	66530	04553
4·7	54·97813	38646	12597	9·7	8158·80362	96494	63643
4·8	60·75932	36328	91950	9·8	9016·87249	16400	55339
4·9	67·14861	31340	03205	9·9	9965·18524	42024	85773
5·0	74·20994	85247	87844	10·0	11013·23292	01033	23140

Corrections of Logarithmic and Other Tables.

Tables of Logarithms to 27 *decimals : Fédor Thoman. Paris,* 1867.
Pages 42, 51 *and* 52.

$\log \frac{1}{45} =$	$\bar{2}$·346787	486224	656320	623683	088
$\log 45 =$	1·653212	513775	343679	376316	912
$\log 55! =$	73·103680	711122	772280	05	

Tables of Logarithms of Factorials : Degen. Copenhagen, 1824.

$\log 137! =$	234·700088	066363	221083	500006
$\log 185! =$	340·615162	028791	001231	205096
$\log 268! =$	535·962496	022591	207008	49205$\underline{8}$
$\log 345! =$	727·384095	927392	776589	468706
$\log 393! =$	850·614919	208496	417262	47557$\underline{8}$
$\log 397! =$	861·003498	218637	078989	486725

Tables of Bessel Functions—Meissel, reprinted in the Treatise on Bessel Functions, Gray and Mathews, first and second editions.

$J_0(0·62) = +0·906184$	297124	$J_4(5) = +0·391232$	360458	648178
$J_0(1·89) = +0·287631$	264839	$J_{23}(6) = +0·$	2	495677
$J_0(3·07) = -0·282862$	262230	$J_{30}(14) = +0·$	16775	399534
$J_0(5·90) = +0·122033$	354593	$J_{31}(16) = +0·$	152594	322163
$J_1(7·87) = +0·214074$	933156			

Meissel's Tables of $J_0(x)$ and $J_1(x)$ to twelve places of decimals were differenced some years ago and led to the discovery of a small number of errors : the tables of $J_n(p)$ were checked by the various relations between the trigonometrical and the Bessel functions.

Photographs of Geological Interest.—*Twenty-second Report of Committee* (Professors E. J. Garwood, *Chairman*; S. H. Reynolds, *Secretary*; Mr. G. Bingley, Mr. C. V. Crook, Mr. A. S. Reid, Professor W. W. Watts, *and* Mr. R. Welch).

Since the publication of the previous report (Liverpool, 1923), the Committee has suffered severe loss in the death of several of its oldest members, Dr. T. G. Bonney, Dr. R. Kidston, Sir J. J. H. Teall, and Mr. W. Whitaker.

Since the issue of the previous report the Committee has had presented to it by Mr. F. W. Reader the great collection of geological negatives made by his brother the late Mr. T. W. Reader. These photographs were mainly taken on the excursions of the Geologists' Association, which Mr. T. W. Reader regularly attended for many years. They form an unique series, and are particularly important in the illustrations they afford of the geology of the Home Counties, which have hitherto not been well represented in the collection. A large proportion of the negatives were accompanied by one or more prints. Time has not yet allowed the whole to be thoroughly dealt with, but 611 prints from the Reader collection are listed in the present report.

The Committee wish to repeat their very hearty thanks to Mr. F. W. Reader for his most valuable and important gift.

The task of getting the Reader photographs described, prior to listing, was a very heavy one, and could not have been accomplished had not the Secretary received unstinted help from many geologists, including the leaders of the excursions on which many of the photographs were taken. The Committee are particularly indebted to Miss M. S. Johnston, who most kindly transcribed on to some hundreds of prints the information entered in Mr. Reader's own albums, which are now in her possession.

Hearty thanks are tendered to the following for help in the description of the Reader photographs—Mr. G. Barrow, Dr. B. Pope Bartlett, Mr. C. J. Bayzand, Dr. H. H. Bemrose, Dr. F. W. Bennett, Prof. P. G. H. Boswell, Mr. S. S. Buckman, Mr. E. St. J. Burton, Mr. H. Bury, Miss M. E. J. Chandler, Mr. R. H. Chandler, Mr. E. S. Cobbold, Prof. A. H. Cox, Prof. A. Morley Davies, Mr. E. H. Davison, Mr. G. E. Dibley, Mr. E. E. L. Dixon, Mr. E. W. Handcock, Prof. H. L. Hawkins, Mr. R. S. Herries, the Rev. E. Hill, Mr. J. W. Jackson, Prof. P. F. Kendall, Mr. W. B. R. King, Dr. W. D. Lang, Mr. A. L. Leach, Mr. H. W. Monckton, Dr. G. M. Part, Mr. R. W. Pocock, Mr. S. Priest, Mr. L. Richardson, Mr. H. C. Sargent, Mr. C. Davies Sherborn, Dr. R. L. Sherlock, Mr. Ll. Treacher, Mr. J. W. Tutcher, Mr. G. W. Young.

The Committee particularly wish to thank Dr. W. D. Lang for the very large amount of trouble he has taken in minutely describing, with the aid of lettered sketches, the photographs illustrating the Dorsetshire Lias. There is nothing in the Committee's collection to vie with these in artistic completeness.

The total number of photographs listed in the present report is 869.

In most years the collection received from the Isle of Wight would be the most important of the year. It forms a set of eighty, all photographed and described by Mr. J. F. Jackson, F.G.S., and was presented in part by Mr. F. Morey and in part after his lamented death by his sister Miss C. Morey.

The Committee are glad to welcome new contributors in Mr. A. W. Coysh, Mr. C. S. Garnett, and Mr. G. G. Lewis.

Mr. Tutcher sends a further series of his excellent photographs illustrating the Lias of Somerset, Mr. E. H. Davison a valuable series from Cornwall, and Mr. P. B. Roberts an interesting set from Wicklow. Mr. A. L. Leach and the Secretary contribute photographs from Norfolk. The Committee has acquired, by purchase, some of Mr. J. H. Savory's remarkable flashlight photographs of the Mendip caves and some of Mr. Amos's views of the Dover cliffs. Prof. Cox sends copies of photographs illustrating his papers on the geology of Cader Idris, and the Abereiddy and Abercastle districts of Pembrokeshire. These were taken by Mr. N. G. Blackwell.

The negatives of the published series of geological photographs which had been missing since before the war have fortunately been recovered, and prints and lantern slides are obtainable through the Secretary at the following rates :—

					£	s.	d.
1st issue—22 Bromide Prints,	with letterpress,	unmounted	...	...	1	13	0
" 22 "	"	" mounted on cards		...	2	4	0
" 22 Lantern Slides	"	" ...	... ...	...	2	4	0
2nd issue—25 Bromide Prints	"	" unmounted	...	...	1	18	0
" 25 "	"	" mounted on cards		...	2	10	0
" 25 Lantern Slides	"	" ...	... ...	...	2	10	0
3rd issue—23 Bromide Prints	"	" unmounted	...	...	1	14	6
" 23 "	"	" mounted on cards		...	2	6	0
" 23 Lantern Slides	"	" ...	... ...	...	2	6	0

The Committee recommend that they be reappointed.

TWENTY-SECOND LIST OF GEOLOGICAL PHOTOGRAPHS.

From September 1, 1923, to May 31, 1926.

List of the geological photographs received and registered by the Secretary of the Committee since the publication of the last report.

Contributors are asked to affix the registered numbers, as given below, to their negatives, for convenience of future reference. Their own numbers are added in order to enable them to do so. Copies of photographs desired can, in most instances, be obtained from the photographer direct. The cost at which copies may be obtained depends on the size of the print and on local circumstances over which the Committee have no control.

The Committee do not assume the copyright of any photograph included in this list. Inquiries respecting photographs, and applications for permission to reproduce them, should be addressed to the photographers direct.

Copies of photographs should be sent, unmounted, to

Professor S. H. Reynolds,
The University, Bristol,

accompanied by descriptions written on a form prepared for the purpose, copies of which may be obtained from him.

The size of the photographs is indicated as follows :—

L=Lantern size.	1/1=Whole plate.
1/4=Quarter-plate.	10/8=10 inches by 8.
1/2=Half-plate.	12/10=12 inches by 10, &c.

E signifies Enlargement.

ACCESSIONS.

England.

Berkshire.—*Photographed by the late* T. W. Reader *and presented by* F. W. Reader. 1/4.

6311	Knowl Hill, between Maidenhead and Twyford	Clay pit in Reading beds. 1911.
6312	Knowl Hill, between Maidenhead and Twyford	Brickfield in Reading beds. 1911.
6313	Knowl Hill, between Maidenhead and Twyford	Sun-cracked clay (Reading beds). 1911.
6314	Warren Row, near Wargrave .	Reading beds resting on chalk. 1911.
6315	Warren Row, near Wargrave .	Reading beds resting on chalk. 1911.
6316	Uffington	Gault section in brickyard S. of station. 1913.
6317	Uffington	Gault section in brickyard S. of station. 1913.
6318	Faringdon	L. Greensand, Faringdon Pit. 1913.
6319	Faringdon . . .	L. Greensand, Faringdon Pit. 1913.
6320	Little Coxwell, Faringdon . .	L. Greensand fossils in relief, Windmill Pit. 1913.
6321	( ) Little Coxwell, Faringdon .	Hard band in L. Greensand sponge gravel, Windmill Pit. 1913.

6322	Little Coxwell, Faringdon . .	Sponge gravel, L. Greensand. 1913.
6323	Little Coxwell, Faringdon . .	Sponge gravel, L. Greensand. 1913.
6324	Little Coxwell, Faringdon . .	Sponge gravel, L. Greensand. 1913.
6325	Little Coxwell, Faringdon . .	Sponge gravel, L. Greensand. 1913.

BUCKINGHAMSHIRE.—*Photographed by the late* T. W. READER *and presented by* F. W. READER. 1/4.

6326	(1) Whiteleaf Hill, near Princes Risboro	Escarpment of Chiltern Hills. 1912.
6327	(3) Whiteleaf Hill, near Princes Risboro	Pipe in Chalk filled with clay with flints. 1912.
6328	(5) Near Longdown Farm, Princes Risboro	Beech-trees on clay with flints. 1912.
6329	(6) Chequers Park	Combe in Chalk. 1912.
6330	(7) Combe Hill, near Wendover .	Chalk escarpment. 1912.
6331	Penn Lands brickfield, Hedgerley	Section of Reading beds. 1910.
6332	Saunders' brickfield, Hedgerley .	Implement-bearing gravel overlying London clay. 1910.

CAMBRIDGESHIRE.—*Photographed by the late* T. W. READER *and presented by* F. W. READER. 1/4.

6333	(4) Upware. S. pit . . .	Coralline Oolite.
6334	(5) Upware. S. pit . . .	Coralline Oolite.
6335	(6) Upware. N. end of S. pit .	'Rag' beds formed of *Thamnastræa.*

CORNWALL.—*Photographed by the late* T. W. READER *and presented by* F. W. READER. 1/4.

6336	(6) Land's End	Granite cliffs and stacks.
6337	(5) Land's End	Well-jointed granite cliffs, joints nearly vertical.
6338	(4) Land's End	Well-jointed granite cliffs.
6339	(1) Land's End	Granite cliffs showing jointing.
6340	(2) Land's End	Granite cliffs.
6341	(3) Land's End and Longships .	Granite cliffs and stacks.
6342	W. of Clodgy Point . . .	Slate cliffs and stacks and Pliocene peneplain.
6343	Zennor	Sea caves in granite cliffs.
6344	Zennor	Granite cliffs, principal joints inclined at angle of about 40°.
6345	Zennor	Granite cliffs, principal joints inclined at angle of about 35°.
6346	Luxulyan Valley . . .	Granite logan stone.
6347	Kynance Cove	Serpentine cliffs.
6348	Lizard Point from above Housel Bay	Hornblende gneiss cliffs and inlet due to collapsed sea cave.
6349	Porth, 1 m. E. of Newquay .	Inlet in Devonian slate.

Photographed by E. H. DAVISON, B.Sc., *School of Mines, Camborne.* $2\frac{1}{4} \times 3\frac{1}{2}$.

6350	Tvethosa, St. Stephen's . .	Sluicing in china-clay pit.
6351	St. Stephen's	Tvethosa china-clay pit.
6352	Tremorebridge, near Lanivet .	Granite porphyry dyke in calc-flinta.

Photographed under the direction of E. H. DAVISON, B.Sc., *School of Mines, Camborne.* Post-card and 1/4.

6353	St. Michael's Mount . . .	The island is half slate, half granite. 1922. P.C.
6354	St. Michael's Mount . . .	Greisen veins in granite. P.C

6355	Foreshore, S. side St. Michael's Mount	Greisen bands in granite. 1/4.
6356	Gwithian, cliffs opposite Godrevy Lighthouse	Undercutting by the sea. 1922. P.C.
6357	Gwithian, cliffs opposite Godrevy Lighthouse	Disturbed lower Palæozoic slates and grits. 1922. P.C.
6358	Cliffs at Godrevy, near Gwithian	Mylor slates folded and overthrust. P.C.
6359	North Cliffs, Camborne	Pliocene platform above slate cliffs. 1922. P.C.
6360	Mullion Is., Lizard	Veryan rocks with spilite and radiolarian chert. 1922. P.C.
6361	Ballswidden, St. Just-in-Pendeen	Development of china-clay pit. 1/4.
6362	Tregargas Qu., St. Stephen's	Quarry in china stone. 1922. P.C.
6363	St. Erth sandpit	Pliocene sands and clays. 1922. P.C.
6364	Carn Brea, Redruth	Granite tor, showing aplite veins. 1/4.
6365	Carn Brea, Redruth	Hollows in granite due to rain and wind. 1923. P.C.

Derbyshire.—*Photographed by the late* T. W. Reader *and presented by* F. W. Reader. 1/4.

6366	(1) Tideswell Dale	Spheroidal weathering of dolerite sill. 1914.
6367	(4) Knott Low, Miller's Dale	Upper lava, on bedded tuff on Carboniferous Limestone. 1914.
6368	(5) Knott Low, Miller's Dale	Upper lava, on bedded tuff on Carboniferous Limestone. 1914.
6369	(6) Knott Low, Miller's Dale	Upper lava, on bedded tuff on Carboniferous Limestone. 1914.
6370	(7) Knott Low, Miller's Dale	Upper lava, on bedded tuff on Carboniferous Limestone. 1914.
6371	(8) Calton Hill, near Miller's Dale	Basalt quarry in vent. 1914.
6372	(9) Calton Hill, near Miller's Dale	Imperfect columnar structure in basalt of vent. 1914.
6373	(10) Calton Hill, near Miller'sDale	Imperfect columnar structure in basalt of vent. 1914.
6374	(11) Shothouse spring between Winster and Grange Mill	Spring issues at junction between limestone and underlying tuff. 1914.
6375	(12) N. of Grange Mill	Hills composed of agglomerate of vent. 1914.
6376	(13) Via Gellia, Matlock Bath	Spring thrown out at top of lower lava. 1914.
6377	(14) Via Gellia, Matlock Bath	Spring thrown out at top of lower lava. 1914.
6378	(15) Via Gellia, Matlock Bath	Tufa on limestone. 1914.
6379	(16) Via Gellia, Matlock Bath	Tufa on limestone. 1914.
6380	(18) Ible Quarry, off Via Gellia	Dolerite sill. 1914.
6381	(19) Ible Quarry, off Via Gellia	Dolerite sill. 1914.
6382	(22) Ible Quarry, off Via Gellia	Dolerite sill. 1914.
6383	(24) Bonsall, near Matlock Bath	Columnar dolerite sill. 1914.
6384	(25) Bonsall, near Matlock Bath	Columnar dolerite sill. 1914.
6385	(26) Bonsall, near Matlock Bath	Columnar dolerite sill. 1914.
6386	(27) Bonsall Qu., near Matlock Bath	Sill of columnar dolerite. 1914.
6387	(28) Pig of Lead Quarry, Via Gellia	Lower lava. 1914.
6388	(31) Pig of Lead Quarry, Via Gellia	Spheroidal weathering of lower lava. 1914.
6389	( ) Pig of Lead Quarry, Via Gellia	Spheroidal weathering of dolerite. 1914.
6390	(33) Pig of Lead Quarry, Via Gellia	Spheroidal weathering of lower lava. 1914.
6391	(35) Pig of Lead Quarry, Via Gellia	Spheroidal weathering of lower lava. 1914.
6392	(1) Cromford, Black Rocks	Millstone Grit crag. 1914.

6393	(2) Cromford, Black Rocks . .	Millstone Grit crag. 1914.
6394	(3) Winster	Crag of 4th or Up. Kinderscout grit. 1914.
6395	(4) Winster	Crag of dolomitised limestone. 1914.
6396	(23) Wyedale	Gorge in Carboniferous Limestone. 1914.
6397	(24) Harboro' pit, Brassington .	Mass of sand and clay filling hollow in Carboniferous Limestone. 1914.
6398	(6a) Matlock Bath . . .	Tufa quarry. 1914.
6399	(7) Matlock Bath . . .	Surface of tufa. 1914.
6400	(8) Matlock Bath . . .	Tufa enclosing *Helix*. 1914.
6401	(9) Matlock Bath . . .	Tufa coating twigs. 1914.
6402	(10) Ible	Sandy concretion (scrablag). 1914.
6403	(11) Matlock Bridge . . .	Thin-bedded cherty limestone (D_3). 1914.
6404	(12) Peep of Day Qu., Litton .	D_2 limestone, crowded with corals. 1914.
6405	(13) Peep of Day Qu., Litton .	D_2 limestone, crowded with corals. 1914.
6406	(14) Monsal Dale Station Quarry.	Boulder Clay on Carboniferous Limestone. 1914.
6407	(15) Monsal Dale Station Quarry .	Boulder Clay on Carboniferous Limestone. 1914.
6408	(16) Darley Dale . . .	Weathered surface of crinoidal limestone, 1914.
6409	(17) Tideswell Dale . . .	Dale scenery with limestone crags. 1914.
6410	(18) Ravenstor, Miller's Dale .	Carboniferous Limestone (D_1) with lower Toadstone at base of cliff. 1914.
6411	(5) Alport	Tufa Quarry. 1914.
6412	(6) Alport	Tufa Quarry, holes were formerly occupied by branches of trees. 1914.
6413	(26) River Dakin, Alport . .	Stream forming tufa terraces. 1914.
6414	(27) Dakin Valley, Alport . .	Enlarged joint in limestone.
6415	(28) Dakin Valley, Alport . .	Limestone dale scenery. 1914.
6416	(38) Ridgeway Cutting, Ambergate	Coal seam.
6417	(30) Ridgeway Cutting, Ambergate	Section of Lower Coal Measures. 1914.
6418	(31) Ridgeway Cutting, Ambergate	Section of Lower Coal Measures. 1914.
6419	( ) Bullbridge, Ambergate .	Cone in cone. 1914.
6420	(33) Old Mill near Youlgreave .	'Pendleside' shale unconformable on D_2 limestone. 1914.
6421	(34) Old Mill near Youlgreave .	'Pendleside' shale unconformable on D_2 limestone. 1914.
6422	(35) Old Mill near Youlgreave .	'Pendleside' shale unconformable on D_2 limestone. 1914.
6423	(36) Old Mill near Youlgreave .	'Pendleside' shale unconformable on D_2 limestone. 1914.
6424	(32) Howden Dam . . .	Anticline. 1914.
6425	(29) Cresbroke Dale . . .	Stepping stones across bed of stream dry in summer. 1914.
6426	( ) Crick, Cliff quarry . .	Mamillated surface of Carboniferous Limestone. 1914.
6427	(19) Klondyke Qu., Crick . .	Clay-filled solution cavities in D_2 limestone. 1914.
6428	(35) Klondyke Qu., Crick . .	Clay-filled solution cavities in D_2 limestone. 1914.
6429	(36) Klondyke Qu., Crick . .	Carboniferous Limestone (D_2) capped by glacial drift. 1914.
6430	(33) Hopton Wood, Middleton by Wirksworth	Quarry in Carboniferous Limestone (D_1). 1914.
6431	(3) 'Robin Hood's Stride,' near Winster	Outlier of Kinderscout Grit.
6432	(34) Hopton Wood, Middleton by Wirksworth	Quarry in Carboniferous Limestone (D_1). 1914.
6433	(4) Via Gellia, near Cromford .	Carboniferous Limestone (D_1) surface in part smoothed, ? slickensided. 1914.
6434	(6) N. Darley Qu., near Wensley.	Cherty Carboniferous Limestone with overlying shales (D_2 and D_3). 1914.

6435	(7) Crick, Hilt's Quarry . .	Carboniferous Limestone (D_2), with hollow filled by Boulder Clay. 1914.
6436	(25) Cromford, near Matlock Bath	Cherty Carboniferous Limestone D_2 and D_3. 1914.
6437	(5) High Tor, Matlock . .	Carboniferous Limestone D_2 and D_3. 1914.
6438	(1) Winster	Quarry in dolomitised D_2. 1914.

Photographed by C. S. Garnett, 25 *Crompton Street, Derby.* 1/4.

6439	(1) Miller's Dale. . . .	Cave formed at junction of limestone with impervious 'Toadstone' below. 1922.
6440	(2) Winnat's Pass, Castleton .	Dale in Carboniferous Limestone. 1921.
6441	(3) Crick Cliff	Anticlinal inlier of Carboniferous Lime stone. 1921.
6442	(4) Bonsall Wood Quarry, Via Gellia	Spheroidal 'Toadstone.' 1918.
6443	(5) Ible Quarry, near Matlock .	Chloritization of dolerite along fissure plane. 1922.
6444	(6) Jughole Cave, near Matlock .	Twisted stalactites (anemolites). 1920.
6445	(7) Near Crick	Wall showing contrast when weathered between Millstone Grit and Ganister. 1921.
6446	(8) Windy Knoll, Castleton .	Elaterite in Carboniferous Limestone. 1914.
6447	(9) Chellaston, near Derby . .	Gypsum breccia. 1921.

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6448	(2) Lyme Regis, foreshore E. of Seven Rock Point	Bed 29 (W.D.L.) with *M.* cf. *conybeari.*
6449	(3) Lyme Regis, foreshore E. of Seven Rock Point	Bed 29 (W.D.L.) with *M.* cf. *conybeari.*
6450	(4) Lyme Regis, foreshore at Seven Rock Point	Reefs in middle limestones of Blue Lias.
6451	(5) E. side of Pinney Bay, Lyme Regis	Reefs in limestones in lower part of Blue Lias.
6452	(6) E. side of Pinney Bay, Lyme Regis	Reefs in limestones in lower part of Blue Lias.
6453	(14) Pinney Bay, Lyme Regis .	Blue Lias cliff with White Lias at base.
6454	(15) Pinney Bay, Lyme Regis .	Blue Lias cliff with White Lias at base.
6455	(16) Pinney Bay, Lyme Regis, E. side	Cliff showing whole thickness of Blue Lias.
6456	(17) Pinney Bay, Lyme Regis .	Small fault in White Lias.
6457	(18) Pinney Bay, Lyme Regis .	Marine erosion of White Lias.
6458	(19) Pinney Bay, Lyme Regis .	Undercutting of White Lias by wave action.
6459	(20) Pinney Bay, Lyme Regis .	Undermining of cliff by wave action.
6460	(21) Pinney Bay, Lyme Regis .	White Lias and lower part of Blue Lias.
6461	(22) Pinney Bay, Lyme Regis .	White Lias and lower part of Blue Lias.
6462	(23) Seaton	Deflection of mouth of Axe by shingle bar.
6463	(24) Seaton	Deflection of mouth of Axe by shingle bar.
6464	(25) Seaton	Deflection of mouth of Axe by shingle bar.
6465	(26) Seaton	Shingle beach at mouth of Axe.
6466	(27) Under Hooken . . .	Slipped masses of Chalk (zones of *T. gracilis* and *R. cuvieri*).
6467	(28) Under Hooken . . .	Slipped masses of Chalk (zones of *T. gracilis* and *R. cuvieri*).
6468	(29) Under Hooken . . .	Slipped masses of Chalk (zones of *T. gracilis* and *R. cuvieri*).

6469	(30) Under Hooken and Hooken Cliff	Section from top of *T. gracilis* zone to Up. Greensand.
6470	(31) Hooken Cliff and Pinnacles .	Cliff and slipped masses of Chalk (chiefly zones of *T. gracilis* and *R. cuvieri*) resting on Greensand.
6471	(32) Hooken Cliff and Pinnacles .	Cliff and slipped masses of Chalk (chiefly zones of *T. gracilis* and *R. cuvieri*) resting on Greensand.
6472	(33) Hooken Cliff and Pinnacles .	Cliff and slipped masses of Chalk (chiefly zones of *T. gracilis* and *R. cuvieri*) resting on Greensand.
6473	(34) Hooken Cliff and Pinnacles .	Cliff and slipped masses of Chalk (chiefly zones of *T. gracilis* and *R. cuvieri*) resting on Greensand.
6474	(35) White Cliff, Seaton . .	Cliff of Middle and Lower Chalk resting on Greensand with Trias at the base.
6475	(36) White Cliff, Seaton . .	Cliff of Middle and Lower Chalk resting on Greensand with Trias at the base.
6476	(37) White Cliff, Seaton, from W..	Chalk section, *H. planus* to *R. cuvieri*, with Greensand at base of the cliff.
6477	(38) Coast, Beer to White Cliff, Seaton	Chalk cliffs, chiefly zones of *H. planus* and *R. cuvieri*.
6478	(39) Cliffs W. of Beer Harbour .	Chalk section, *H. planus* to *R. cuvieri*, with Greensand at base of cliff.
6479	(40) Beer Harbour, W. side . .	Chalk section, *H. planus* to *R. cuvieri*, with Greensand at base of cliff.
6480	(41) Beer Harbour, E. side . .	Chalk, *T. gracilis* and *R. cuvieri* zones.
6481	(42) Raven Cliff, N. side of Beer Harbour	Chalk section, *M. cor-testudinarium* to *R. cuvieri*.
6482	(43) Beer Quarry . . .	Chalk, *T. gracilis* and *R. cuvieri* zones.
6483	(44) Annis Knob, Beer Cove .	Chalk, *M. cor-testudinarium* and *H. planus* zones.
6484	Whipcoats near Burlescombe .	Contortions in Lower Culm limestones. 1911.

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6485	(26.19) Lee Moor Pit, near Princetown	China-clay Pit. 1926.
6486	(26.18) Wotter clay-pit near Princetown	Kaolinized aplite veins in granite. 1926.
6487	(26.17) Wotter clay-pit near Princetown	Sluicing China Clay. 1926.

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6488	Thunder Hole, Torquay . .	Fault breccia. 1924.
6489	Hope's Nose, Torquay . .	Overfolded and overthrust Devonian Limestone. 1924.
6490	Dawlish Warren . . .	Fault in Permian Breccia. 1925.

Dorset.—*Photographed by the late* T. W. Reader *and presented by* F. W. Reader. 1/4.

6491	The Agglestone, near Studland .	Hard mass of Bagshot Sandstone.
6492	The Agglestone, near Studland .	Hard mass of Bagshot Sandstone.
6493	Durlston Head, Swanage . .	Marine erosion and fallen blocks of Portland Stone.
6494	Durlston Bay, Swanage . .	Bone in Upper Purbeck. 1910.
6495	Durlston Bay and Peveril Point .	Purbeck Section. 1910.
6496	Durlston Bay, Swanage . .	Purbeck Section. 1910.
6497	Durlston Bay, Swanage . .	Purbeck Section. 1910.

6498	Durlston Bay, Swanage . .	Purbeck Section. 1910.
6499	Peveril Point, Swanage . .	Up. Purbeck Beds. 1910.
6500	Peveril Point, Swanage . .	Up. Purbeck Beds. 1910.
6501	Winspit Qu., near Swanage .	Lower Purbeck on Portland Stone, projecting ledge of chert beds. 1910.
6502	Winspit Qu., near Swanage .	Section Low. Purbeck and Up. Portland. 1910.
6503	Winspit Qu., near Swanage . .	Lower Purbeck on Portland Stone. 1910.
6504	Winspit Qu., near Swanage .	Shows tunnel-working for Portland Stone. 1910.
6505	Near Dancing Ledge . . .	Cliff of Portland Stone overlying Sand, with talus of Portland Stone blocks. 1910.
6506	St. Alban's Head . . .	Breaking away of cliff face along joint planes.
6507	St. Alban's Head . . .	Slipped and fallen masses at foot of cliff. 1910.
6508	Emmet Hill, St. Alban's Head .	Section Low. Purbeck to Kimmeridge Clay. 1910.
6509	(1) Lulworth Cove, E. side . .	Up. Jurassic and Cretaceous section. 1910.
6510	(2) Lulworth Cove . . .	Purbeck and Wealden section. 1910.
6511	(3) Lulworth Cove . . .	Section Portland to Wealden, E. side of Cove. 1910.
6512	(4) Lulworth and Stair Coves .	Stair Cove is eroded in Purbecks, Lulworth Cove is cut back to the Chalk. 1910.
6513	(5) Lulworth Cove . . .	Cliff of overfolded Chalk at head of Cove. 1910.
6514	(6) Stair Cove, Lulworth . .	Contorted Purbecks. 1910.
6515	(7) Stair Cove, Lulworth . .	Portland and L. Purbeck Section, W. end of Cove. 1910.
6516	(8) Stair Cove, Lulworth . .	Screen of Portland and base of Purbeck. 1910.
6517	(9) Stair Cove, Lulworth . .	Breach in screen. 1910.
6518	(10) Stair Cove, Lulworth . .	Breach in screen. 1910.
6519	(11) 'Fossil Forest,' Lulworth .	General view from above. 1910.
6520	(12) 'Fossil Forest,' Lulworth .	Burrs of tufa round tree stumps. 1910.
6521	(13) 'Fossil Forest,' Lulworth .	Burrs of tufa round tree stumps. 1910.
6522	(14) 'Fossil Forest,' Lulworth .	Burrs of tufa round tree stumps. 1910.
6523	Man of War Cove, Lulworth .	Squeezing out of softer bands in disturbed Purbecks. 1910.
6524	(24) Church Cliffs, N.E. of Lyme Regis	Higher beds of Blue Lias.
6525	(25) Church Cliffs, N.E. of Lyme Regis	Higher beds of Blue Lias.
6526	(26) Church Cliffs, N.E. of Lyme Regis	Small fault in highest beds of Blue Lias.
6527	(27) E. of Church Cliffs, N.E. of Lyme Regis	Highest beds of Blue Lias.
6528	(28) Church Cliffs, N.E. of Lyme Regis	Highest beds of Blue Lias.
6529	(29) Church Cliffs, N.E. of Lyme Regis	Highest beds of Blue Lias.
6530	(30) Church Cliffs, N.E. of Lyme Regis	Highest beds of Blue Lias
6531	(31) Church Cliffs, N.E. of Lyme Regis.	Highest beds of Blue Lias.
6532	(32) E. end of Church Cliff, N.E. of Lyme Regis	Mass of shale fallen from the 'Burning Cliff.'
6533	(33) E. end of Church Cliff, N.E. of Lyme Regis	Mass of shale fallen from the 'Burning Cliff.'

6534	(34) Coast Black Ven to Golden Cap	Lias hills capped by Cretaceous.
6535	(35) W. end of Black Ven, Charmouth	Lower Lias capped by Cretaceous.
6536	(36) Middle part of Black Ven, Charmouth	Lias Section.
6537	(37) E. part of Black Ven, Charmouth	Lias Section.
6538	(38) E. part of Black Ven, Charmouth	Lias Section.
6539	(39) E. part of Black Ven, Charmouth	Lias Section.
6540	(40) Foot of Black Ven, Charmouth	Small normal fault in Lias shale.
6541	(41) Foot of Black Ven, Charmouth	Fold in Lias shale near fault.
6542	(42) Foot of Black Ven, Charmouth	Nodule occurring between the two main layers of a beef-seam.
6543	(43) Coast, Charmouth to Golden Cap	Lias hills capped by Cretaceous.
6544	(44) W. part of Black Ven . .	Middle and Upper Lias precipices.
6545	(45) Black Ven, Charmouth, from W.	Lias Section.
6546	(46) W. end of Stonebarrow Cliff, E. of Charmouth	Upper Lias precipice (Belemnite marl).
6547	(47) Mouth of the Char. . .	River-mouth diverted eastward by drift of shingle.
6548	(48) Top of Stonebarrow Cliff, Charmouth	Upper Lias capped by Cretaceous.
6549	(49) Top of Stonebarrow Cliff, Charmouth	Upper Lias capped by Cretaceous.
6550	(50) Top of Stonebarrow Cliff, Charmouth	Upper Lias capped by Cretaceous.
6551	(51) Fairy Dell, Charmouth, with Stonebarrow behind	Upper Lias capped by Cretaceous.
6552	(52) Fairy Dell, Charmouth, with Stonebarrow behind	Upper Lias capped by Cretaceous.
6553	Gillingham brickyard . .	Middle beds of Kimmeridge Clay. 1916.
6554	Gillingham brickyard . .	Middle beds of Kimmeridge Clay. 1916.
6555	Melbury Hill Quarry, two miles S. of Shaftesbury	Junction Lower Chalk and Upper Greensand. 1916.
6556	Between Bradford Abbas and Yeovil	‘Hollow Way’ in Yeovil Sands. 1911.
6557	Trill Farm, Thornford, near Bradford Abbas	Fuller's Earth rock. 1911.
6558	Trill Farm, Thornford, near Bradford Abbas	Fuller's Earth rock. 1911.
6559	Near Trill Farm, Thornford, near Bradford Abbas	Fuller's Earth rock. 1911.
6560	King's Pit, Bradford Abbas . .	Basal Fuller's Earth (? *fuscæ*), and Inferior Oolite (*zigzag*). 1911.
6561	Beggarsbush Lane Quarry, Bradford Abbas	Inferior Oolite. 1911
6562	Beggarsbush Lane Quarry, Bradford Abbas	Detail Inferior Oolite. 1911.
6563	Rock Cottage Quarry, Halfway House, near Sherborne	Inferior Oolite on bored ‘Dew bed’ (hemera *moorei*—Up. Lias). 1911.
6564	Rock Cottage Quarry, Halfway House, near Sherborne	Inferior Oolite on bored ‘Dew bed’ (hemera *moorei*—Up. Lias). 1911.
6565	Rock Cottage Quarry, Halfway House, near Sherborne	Inferior Oolite on bored ‘Dew bed (hemera *moorei*—Up. Lias). 1911.
6566	Chapel Qu., Halfway House, near Sherborne	Inferior Oolite Section. 1911.

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6567	(2) 'Fossil Forest,' Lulworth .	Tufa burr round tree-stump. 1925.
6568	(4) White Nothe, near Lulworth .	Undercliff of slipped Upper Cretaceous. 1925.

Durham.—*Photographed by* Stanley Smith, M.A., D.Sc., *Haughton-le-Skerne, Darlington.* 1/4.

6569	Buckhead Quarry, Cockfield .	Natural coke in contact with andesite.

Essex.—*Photographed by the late* T. W. Reader *and presented by* F. W. Reader. 1/4.

6570	Wenden Mill, Audley End . .	River loam overlying chalky gravel. 1911.
6571	Abbey Farm, Audley End . .	Mass of cemented gravel (calcrete). 1911.
6572	Abbey Farm, Audley End . .	Mass of cemented gravel (calcrete). 1911.
6573	Saffron Walden, near Seward's end	Boulder Clay with Chalk blocks. 1911.
6574	Saffron Walden, near Seward's end	Boulder Clay with Chalk blocks. 1911.
6575	Grays Thurrock . . .	River gravel on Thanet Sand on Chalk. 1910.
6576	Grays Thurrock . . .	River gravel on Thanet Sand on Chalk. 1910.
6577	Grays Thurrock . . .	Sarsens left behind after removal of gravel. 1910.
6578	Grays Thurrock . . .	Mammillated surface of Sarsen Stones. 1910.
6579	Grays Thurrock . . .	Mammillated surface of Sarsen Stones. 1910.

Gloucestershire.—*Photographed by the late* T. W. Reader *and presented by* F. W. Reader. 1/4.

6580	(1) Avon Section (rt.), Clifton, N. end	Section O.R.S. to Bryozoa bed. 1919.
6581	(2) Avon Section (rt.), Clifton .	Bryozoa bed (α), near view. 1919.
6582	(3) Avon Section (rt.), Clifton, Sea Walls	Section K_2—Z_2. 1919.
6583	(4) Avon Section (rt.), Clifton, Black Rock Quarry	Section β—Z_2. 1919.
6584	(5) Avon Section (rt.), Clifton, Black Rock Quarry	Section Z_1—C_1. 1919.
6585	(6) Avon Section (rt.), Clifton, Black Rock Quarry	Section Z_1—C_1. 1919.
6586	(7) Avon Section (rt.), Clifton .	S. end of Black Rock Quarry (γ overlain by *laminosa* dolomite). 1919.
6587	(8) Gully Quarry, Avon Section, Clifton	*Caninia* dolomite (C_2) on *Caninia* oolite (C_1). 1919.
6588	(9) Avon Section (rt.), Clifton .	Section *Caninia* oolite (C_1) to S_1. 1919.
6589	(10) Avon Section (rt.), Clifton .	N. End Great Quarry (S_1). 1919.
6590	(11) Avon Section (rt.), Clifton .	S_1 section N. end Great Quarry. 1919.
6591	(12) Avon Section (rt.), Clifton .	Overthrust, N. end of Great Quarry. 1919.
6592	(13) Avon Section (rt.), Clifton .	Overthrust, N. end of Great Quarry. 1919.
6593	(14) Avon Section (rt.), Clifton .	S_2 section, middle and S. part of Great Quarry. 1919.
6594	(15) Avon Section (rt.), Clifton, S. end Great Quarry	Smoothed, ? slickensided surface. 1919.
6595	(16) Avon Section (rt.), Clifton .	S. end Great Quarry, S_2 and D_1. 1919.
6596	(17) Avon Section (rt.), Clifton .	D_1 beds. 1919.

6597	(18) Observatory Hill, Clifton .	S_2 limestone thrust over disturbed grits and shales of upper D_2. 1919.
6598	(19) Observatory Hill, Clifton .	S_2 limestone thrust over upper D_2 (near view). 1919.
6599	(20) Observatory Hill, Clifton .	Overthrust S_2 beds. 1919.
6600	(21) Clifton, E. buttress of Suspension Bridge	Well-jointed Carboniferous Limestone (S_2). 1919.
6601	(22) Aust Cliff, N. part . .	Red and Grey marls. 1919.
6602	(23) Aust Cliff	Showing projecting mass of cliff in relation to fault. 1919.
6603	(24) Aust Cliff	General view, Red marl to Rhætic. 1919.
6604	(25) Aust Cliff	Showing two projecting masses of cliff in relation to faults. 1919.
6605	(26) Aust Cliff	Section Rhætic, Grey and Red marls. 1919.
6606	(27) Aust Cliff, near N. end .	Lower part of Red marl with gypsum. 1919.
6607	(28) Aust Cliff, near N. end .	Gypsum masses in Red marl. 1919.
6608	(29) Aust Cliff, near N. end .	Vertical gypsum masses in Red marl. 1919.

Photographed by J. W. Tutcher, 57 *Berkeley Road, Bishopston, Bristol.* 1/2 *and* 1/4.

6609	(C) Brentry Quarry, 1¼ mile N. of Westbury-on-Trym	Algal layers of S_2 beds. 1913. 1/4.
6610	(E) Brentry Quarry, 1¼ mile N. of Westbury-on-Trym	Nearly vertical S_2 beds. 1913. 1/2.
6611	(I) Willsbridge Quarry, near Bitton	L. Lias, *semicostatus* clay, with *bucklandi* beds below. 1902. 1/2.
6612	(J) ½ mile W. of Bitton Station.	L. Lias, upper *angulatus* and lower *bucklandi* beds. 1902. 1/2.
6613	(K) Willsbridge Quarry, near Bitton.	Lower Lias, *angulatus* zone. 1902. 1/2.

Photographed by S. H. Reynolds, M.A., Sc.D., *The University, Bristol.* 1/2 *and* 1/4.

6614	(23·100) St. Monica's, Westbury-on-Trym	Top of O.R.S. and base of Carboniferous. 1923. 1/2.
6615	(24·15) St. Monica's, Westbury-on-Trym	Top of O.R.S. and base of Carboniferous. 1924. 1/2.
6616	(22·41) Road cutting, Portway, Shirehampton	O.R.S. alternating sandstone and shale. 1922. 1/4.
6617	(22·40) Road cutting, Portway, Shirehampton	O.R.S. shale and sandstone. 1922. 1/4.
6618	(22·42) Road cutting, Portway, Shirehampton	Trias conglomerate on uneven surface of disturbed O.R.S. 1922. 1/4.
6619	(39·22) Road cutting, Portway, Shirehampton	Trias on O.R.S. 1922. 1/4.
6620	(23·102) Road cutting, Portway, Shirehampton	Disturbed O.R.S. 1923. 1/4.

Hampshire (Isle of Wight).—*Photographed by* J. F. Jackson, F.G.S., 2 *St. Thomas's Square, Newport, I.W., and presented by the late* F. Morey *and by* Miss C. Morey. 1/4.

6621	(70) Freshwater Bay . . .	Ruins of the sea wall. 1924.
6622	(72) Freshwater Bay, W. side .	Marine erosion. 1924.
6623	(150) Freshwater Bay, E. side .	Highly inclined Chalk with flints. 1925.
6624	(58) Scratchell's Bay . . .	Highly inclined Upper Chalk. 1924.
6625	(106) Alum Bay, N. of the Pier .	Lower Headon overlying Barton sands. 1924.

6626	(158)	Alum Bay, N. of the Pier .	Barton sands overlying Upper Barton clay. 1925.
6627	(159)	Alum Bay . . .	Conglomerate in Bracklesham beds. 1925.
6628	(155)	Alum Bay . . .	Pipeclay leafbed in Bagshot sands. 1925.
6629	(52)	Alum Bay	General view, vertical Eocenes. 1924.
6630	(137)	Alum Bay, S. end . .	Slip of Lower Eocenes. 1925.
6631	(139)	Alum Bay, S. end . .	Concretionary structure in Reading beds. 1925.
6632	(140)	Alum Bay, S. end . .	Concretionary masses in Reading beds. 1925.
6633	(54)	Alum Bay, S. end . .	Rain channels in base of vertical Reading beds. 1924.
6634	(160)	Alum Bay, S. end . .	'Mud glaciers' on outcrop of Reading beds. 1925.
6635	(62)	Headon Hill . . .	Freshwater limestone with shells in situ. 1924.
6636	(65)	Top of Headon Hill . .	Coarse plateau gravel. 1924.
6637	(82)	Headon Hill, S. end . .	*Potamides ventricosus* bed (Mid. Headon). 1924.
6638	(105)	Headon Hill . . .	Detail, conglomeratic Upper Headon limestone. 1924.
6639	(103)	Headon Hill . . .	Upper Headon freshwater limestone. 1924.
6640	(60)	Headon Hill, N.E. face .	Upper Headon overlying Middle Headon. 1924.
6641	(67)	Headon Hill . .	*Potamides ventricosus* bed (Mid. Headon). 1924.
6642	(50)	Colwell Bay, between Colwell Chine and Bramble's Chine	*Ostrea velata* bank (Mid. Headon). 1924.
6643	(98)	Colwell Bay, N. of Linstone Chine	Anticline in Upper and Middle Headon. 1924.
6644	(48)	Colwell Bay, S. end . .	Middle and Lower Headon. 1925.
6645	(87)	One mile E. of Yarmouth Pier	Disruption of sea wall by slips of Bembridge marl. 1924.
6646	(47)	Totland Bay, 100 yards N. of Pier	Fallen block of Warden Ledge sands (Lower Headon). 1924.
6647	(17)	Bouldnor Cliff, Hamstead .	A 'mud glacier.' 1924.
6648	(89)	Bouldnor Cliff, Hamstead .	Mud fall in chief 'mud glacier.' 1924.
6649	(30)	Thorness Bay, S.W. of Cowes	Effect of slipping and marine erosion on cliffs of soft sand and clay. 1924.
6650	(32)	Near Sticelett Ledge, Thorness Bay, Cowes	Hard shelly bands in Bembridge marl. 1924.
6651	(94)	Cliffs between Gurnard Point and Thorness Marsh, Cowes	Anticline in Bembridge marls. 1924.
6652	(95)	Cliffs between Gurnard Point and Thorness Marsh, Cowes	Overthrust in Bembridge marls. 1924.
6653	(35)	Gurnard Ledge, Gurnard Point, S.W. of Cowes	Marine erosion of Bembridge limestone. 1924.
6654	(36)	Gurnard Bay, Cowes . .	Cliff of Bembridge limestone overlying Osborne beds. 1924.
6655	(45)	E. of Dropping Well Cottages, St. George's Down, Newport	Pit in plateau gravel. 1924.
6656	(24)	N.E. side, St. George's Down, Newport	Coarse plateau gravel resting on Sandrock series. 1924.
6657	(169)	Cliff near Howgate Farm, S.W. of the Foreland, Bembridge	Brick earth resting on raised beach. 1925.
6658	(168)	Cliff near the Foreland, Bembridge	Detail of raised beach. 1925.
6659	(167)	Cliff near the Foreland, Bembridge	Cliff of raised beach and shingle. 1925.
6660	(166)	Cliff near the Foreland, Bembridge	Raised beach resting on Bembridge marl. 1925.

6661	(79) Whitecliff Point, Whitecliff Bay	Junction Whitecliff marl and limestone. 1924.
6662	(38) Whitecliff Bay . . .	Undercutting of fallen blocks of Bembridge limestone by wave action. 1924.
6663	(43) Culver Cliff, N.E. corner .	Highly inclined *quadratus* and *mucronata* chalk. 1924.
6664	(151) E. end of Culver Cliff .	Sea-caves, 'The Nostrils.' 1925.
6665	(119) Shanklin Point . . .	Ferruginous concretions from Sandrock series. 1924.
6666	(129) Luccombe Bay . . .	Marine erosion of slipped Gault clay. 1925.
6667	(131) Near Bonchurch . .	General view of slip. 1925.
6668	(133) Wheeler's Bay and cliffs of High Port, Ventnor	Cliffs of slipped Chalk and other material. 1925.
6669	(135) Cliffs of High Port, Ventnor	Detail of slipped chalky clay. 1925.
6670	(192) Gore Cliff, E. end . .	Detail, chert beds of Upper Greensand. 1925.
6671	(165) E. end Gore Cliff . .	Large slipped masses of Chalk and Upper Greensand. 1925.
6672	(190) Gore Cliff and the landslip above Rocken End	Upper Greensand section. 1925.
6673	(189) Edge of Gore Cliff . .	Slow detachment of large mass of rock. 1925.
6674	(56) Gore Cliff, seen from the sea off Rocken End	Upper Greensand cliff overlooking landslip. 1924.
6675	(107) Gore Cliff, between Niton and Blackgang	Upper Greensand section. 1924.
6676	(191) Brow of Gore Cliff . .	Chalky rainwash 9 feet thick resting on Chalk Marl. 1925.
6677	(109) Shore at Rocken End .	Fallen block showing junction of Upper Greensand and Chloritic Marl. 1924.
6678	(144) Rocken End . . .	Block of Upper Greensand showing honeycomb weathering. 1925.
6679	(163) Cliffs N.W. of Rocken End .	Detail base of Sandrock series. 1925.
6680	(162) Cliffs N.W. of Rocken End .	Base of Sandrock series with slipped blocks of sandstone. 1925.
6681	(170) Mouth of Blackgang Chine .	Erosion of Lower Greensand. 1925.
6682	(171) Mouth of Walpen Chine, Chale Bay	Stream erosion in cliff of Ferruginous Sand. 1925.
6683	(172) Mouth of Ladder Chine, Chale Bay	Worn in Ferruginous Sand chiefly by wind erosion. 1925.
6684	(173) Ladder Chine, Chale Bay .	Erosion of Ferruginous Sand. 1925.
6685	(115) N.W. of Whale Chine, Chale Bay	Ferruginous Sands with *Exogyra sinuata*. 1925.
6686	(175) Whale Chine, Chale Bay .	Ravine in Ferruginous Sands. 1925.
6687	(184) Ladder Chine, Chale Bay .	Wind-erosion of Lower Greensand. 1925.
6688	(174) Ladder Chine, Chale Bay .	Wind-erosion of Lower Greensand. 1925.
6689	(114) The Cracker's Rocks, Atherfield	Concretions in undercut Ferruginous Sands. 1924.
6690	(188) N.W. side of Atherfield Point	Part of huge founder of Atherfield Clay and Wealden shale. 1925.
6691	(176) Shepherd's Chine, Atherfield	Stream ponded back by small landslip. 1925.
6692	(111) Chilton Chine, W.S.W. of Brighstone	False-bedded Wealden sandstone. 1924.
6693	(113) Bull Rocks near Chilton Chine	Wealden sandstone and marl. 1925.
6694	(112) Sedmore Point, between Brook Bay and Brighstone Bay	Ripple marks and sun cracks in block of Wealden marls. 1924.
6695	(183) Cowleaze Chine . .	Undercutting of Wealden sandstone by splash from small waterfall. 1925.
6696	(181) Cowleaze Chine . .	Waterfall due to sandstone band in soft Wealden shale. 1925.
6697	(180) Cowleaze Chine . . .	Sandstone band in Wealden shale. 1925.

6698	(178) Cowleaze Chine . . .	Eroded in Wealden. 1925.
6699	(179) Cowleaze Chine . . .	Eroded in Wealden. 1925.
6700	(177) Cliffs at mouth of Cowleaze Chine	Wealden Section. 1925.

Photographed by the late T. W. Reader *and presented by* F. W. Reader. 1/4.

6701	Brickfield ½ mile N.E. of Nately Scures Church	London Clay with fossiliferous septaria. 1911.
6702	Near Upper Nately Church .	Sandstone band in Reading beds. 1911.
6703	Brickfield ¼ mile N.W. of Upper Nately Church	London Clay with basement bed resting on Reading beds. 1911.
6704	Bournemouth Cliffs about ¼ mile E. of pier	Middle Eocenes. 1910.
6705	Bournemouth Cliffs about ¼ mile E. of pier	Cliffs of Boscombe Sand. 1910.
6706	Bournemouth Cliffs, E. of Step Chine	Boscombe Sands capped by plateau gravel. 1910.
6707	Bournemouth Cliffs near East Cliff lift	Section of 'marine' beds in lower part of Boscombe Sands. 1910.
6708	Bournemouth Cliffs . . .	Tertiary Section. 1910.
6709	Durley Chine, Bournemouth .	Concretionary sandstone masses in Middle Bagshot. 1910.
6710	Durley Chine, Bournemouth .	Concretionary sandstone masses in Middle Bagshot. 1910.
6711	Bournemouth Cliffs, midway between Bournemouth and Boscombe	Plateau gravel capping Boscombe Sands. 1910.
6712	Bournemouth Cliffs, W. of Boscombe Pier	Middle Eocene. 1910.
6713	Cliffs near steps, W. of Boscombe pier	Boscombe Sand with slip in foreground. 1910.
6714	Bournemouth Cliffs, 200-300 yds. W. of Boscombe Pier	Middle Eocenes. 1910.
6715	Honeycombe Chine, 250 yds. E. of Boscombe Pier	Boscombe Sands, overlying Bournemouth marine beds. 1910.
6716	Honeycombe Chine, 250 yds. E. of Boscombe Pier	Boscombe Sands, overlying Bournemouth marine beds. 1910.
6717	Honeycombe Chine, 250 yds. E. of Boscombe Pier	Boscombe Sands, overlying Bournemouth marine beds. 1910.
6718	Honeycombe Chine, 250 yds. E. of Boscombe Pier	Bournemouth marine beds. 1910.
6719	Honeycombe Chine, 250 yds. E. of Boscombe Pier	Bournemouth marine beds. 1910.
6720	Honeycombe Chine, 250 yds. E. of Boscombe Pier	Bournemouth marine beds. 1910.
6721	Honeycombe Chine, 250 yds. E. of Boscombe Pier	Bournemouth marine beds. 1910.
6722	Honeycombe Chine, 250 yds. E. of Boscombe Pier	Plateau gravel, capping Boscombe Sands, overlying Bournemouth marine beds. 1910.
6723	Honeycombe Chine, 250 yds. E. of Boscombe Pier	Plateau gravel, capping Boscombe Sands, overlying Bournemouth marine beds. 1910.
6724	Honeycombe Chine, 250 yds. E. of Boscombe Pier	Plateau gravel, capping Boscombe Sands, overlying Bournemouth marine beds. 1910.
6725	Honeycombe Chine, 250 yds. E. of Boscombe Pier	Plateau gravel, capping Boscombe Sands, overlying Bournemouth marine beds. 1910.
6726	Honeycombe Chine, 250 yds. E. of Boscombe Pier	Plateau gravel, capping Boscombe Sands, overlying Bournemouth marine beds. 1910.

6727	Honeycombe Chine, 250 yds. E. of Boscombe Pier	Plateau gravel, capping Boscombe Sands, overlying Bournemouth marine beds. 1910.
6728	(A) Barton-on-Sea, near Barton Court Hotel	Middle and Upper Barton, slipped and in situ.
6729	(C) Barton-on-Sea, cliffs W. of Barton Court Hotel	Pleistocene gravel capping Upper Barton.
6730	(D) Barton-on-Sea, cliffs W. of Barton Court Hotel	Pleistocene gravel capping Upper Barton.
6731	(E) Barton-on-Sea, cliffs W. of Barton Court Hotel	Pleistocene gravel capping Upper Barton Sands.
6732	(F) Barton-on-Sea, cliff looking E.	Pleistocene gravel capping Upper Barton Sands.
6733	(G) Barton-on-Sea, W. of Barton Court Hotel	Middle Barton Clay with septaria.
6734	(H) Barton-on-Sea, cliffs W. of Barton Court Hotel	Middle Barton Clay with septaria.
6735	(I) Barton-on-Sea, cliffs W. of Barton Court Hotel	Middle Barton Clay with septaria.
6736	(J) Barton-on-Sea, W. of Barton Court Hotel	Pleistocene gravel capping Upper Barton Sand.
6737	(K) Barton-on-Sea, W. of Barton Court Hotel	Pleistocene gravel capping Upper Barton Sand.

HEREFORDSHIRE.—*Photographed by* S. H. REYNOLDS, M.A., Sc.D., *The University, Bristol.* 1/4.

6738	(25·26) Prior's Frome, Woolhope Inlier	Upper Ludlow and Downtonian section. 1926.
6739	(23·26) Scutterdine Quarry, Woolhope	Woolhope Limestone. 1926.
6740	(24·26) Scutterdine Quarry, Woolhope	Woolhope Limestone. 1926.
6741	(21·26) Sufton Cockshoot Quarry, Woolhope	Well-jointed Aymestry Limestone. 1926.
6742	(22·26) Sufton Cockshoot Quarry, Woolhope	Rubbly Aymestry Limestone. 1926.
6743	(26·26) Cockshoot Quarry, Woolhope	Aymestry Limestone. 1926.
6744	(27·26) Rushall, Woolhope . .	Ludlow Bone-bed equivalent and adjacent strata. 1926.
6745	(28·26) Rushall, Woolhope . .	Ludlow Bone-bed equivalent and adjacent strata. 1926.
6746	(29·26) Near Ethelbert's Camp, Woolhope	Aymestry and Wenlock escarpments. 1926.

HERTFORDSHIRE.—*Photographed by the late* T. W. READER *and presented by* F. W. READER. 1/4.

6747	Arlesey, Beart's Brick Works .	Chalk Marl with Cambridge Greensand at base resting on Gault. 1910.
6748	Letchworth Station . . .	Boulder Clay overlying sand. 1910.
6749	Watford Heath	Basement bed of London Clay. 1911.
6750	Bushey cutting	Base of London Clay and Reading beds. 1911.
6751	Oxhey golf course . . .	Reading sands with bedded flint pebbles. 1911.
6752	Oxhey	Bottom pebble bed of Reading series. 1911.
6753	Bishop's Stortford (cemetery) .	Sarsen with bands of pebbles.
6754	Bishop's Stortford, Day's brickyard	Mottled Reading Clay. 1911.
6755	Bishop's Stortford, Foxdells .	Section in rubble drift. 1911.

6756	Bishop's Stortford, Day's brick-yard	Mottled Reading clay. 1911.
6757	(1) Ware	Glacial sands and gravels. 1915.
6758	(2) Ware	Glacial sands and gravel. 1915.
6759	(3) Ware	Glacial sand and gravel, marked cross-bedding. 1915.
6760	(4) Ware, claypit of Ware Brick-fields, Ltd.	Laminated glacial clay. 1915.
6761	(5) Ware, claypit of Ware Brick-fields, Ltd.	Glacial sand and gravel overlain by boulder clay. 1915.
6762	(6) Ware, claypit of Ware Brick-fields, Ltd.	Glacial sand and gravel overlain by boulder clay. 1915.
6763	(8) Tyttenhanger Pit, near St. Albans	Boulder clay and glacial sands. 1913.
6764	(9) Tyttenhanger Pit, near St. Albans	Boulder clay and glacial sands and gravel, 1913.
6765	(10) Near St. Albans, ? Hill End Pit	Chalky boulder clay on glacial sand and gravel. 1913.
6766	(11) Near St. Albans, ? Hill End Pit	Chalky boulder clay on glacial sand and gravel. 1913.
6767	(12) Hill End Pit, near St. Albans	Chalky boulder clay on contorted sand and gravel. 1913.
6768	(13) Hill End Pit, near St. Albans	Contorted gravel underlying chalky boulder clay. 1913.
6769	(14) Hill End Pit, near St. Albans	Contorted glacial gravel. 1913.
6770	(15) Hill End Pit, near St. Albans	Chalky boulder clay overlying glacial sand and gravel. 1913.
6771	(16 Hill End Pit, near St. Albans	False-bedded glacial sand and gravel. 1913.
6772	(17) N. of Cuffley . . .	Block of Hertfordshire puddingstone. 1913.
6773	(18) N. of Cuffley . . .	Block of Hertfordshire puddingstone. 1913.
6774	(19) Bayfordbury Park, near Hertford	Boulder clay on glacial gravel and sand. 1913.
6775	(20) Railway cutting E. of Bayford	Boulder clay and sand. 1913.
6776	(21) Railway cutting E. of Bayford	Boulder clay and sand. 1913.
6777	Tunnel, 1 mile N. of Hertford .	Gravel and boulder clay overlying chalk. 1914.
6778	Watton Cutting, Hertford . .	Boulder clay and gravel. 1914.
6779	Watton Cutting, Hertford . .	Boulder clay and gravel. 1914.
6780	N. end, Watton Cutting, Hertford	Current-bedded gravel with large sand lenticles below boulder clay. 1914.
6781	N. end, Watton Cutting, Hertford	Current-bedded gravel with large sand lenticle below boulder clay. 1914.
6782	N. end, Watton Cutting, Hertford	Current-bedded gravel below boulder clay. 1914.
6783	Stevenage	Cutting in boulder clay. 1914.

Photographed by G. G. Lewis, *Ellerslie Road School, London, W.* 12. 1/4.

6784	Between Rickmansworth and Harefield	Current bedding in glacial gravel. 1925.
6785	Between Rickmansworth and Harefield	Erosion channel in Chalk filled with glacial gravel. 1925.

Kent.—*Photographed by the late* T. W. Reader *and presented by* F. W. Reader. 1/4.

6786	Herne Bay	Upper part Thanet Sands and base of Reading beds. 1912.
6787	Herne Bay	Palæolithic gravels. 1912.
6788	Herne Bay	Section London Clay to Thanet beds. 1912.

6789	E. of Oldhaven Gap, Herne Bay .	London Clay, Oldhaven beds, and Woolwich and Reading beds. 1912.
6790	E. of Oldhaven Gap . . .	Cliff of Woolwich and Reading beds capped by London Clay. 1912.
6791	Cliffs E. of Oldhaven Gap . .	London Clay overlying Lower London Tertiaries. 1912.
6792	Near Oldhaven Gap . . .	Block of hardened sand weathered out from Woolwich and Reading beds. 1912.
6793	W. of Oldhaven Gap . . .	London Clay resting on Oldhaven beds with Woolwich and Reading beds below. 1912.
6794	Coast between Oldhaven Gap and Reculvers	Hard layers in Upper Thanet Sands. 1912.
6795	Between Oldhaven Gap and Reculvers	Slabs of sandstone in Upper Thanet Sands. 1912.
6796	Coast W. of Reculvers . .	Cliffs of Lower London Tertiaries, shore strewn with hard blocks from Thanet Sands. 1912.
6797	Reculvers Church . . .	Protection of cliff (Thanet Sands) by groynes. 1912.
6798	Reculvers Church . . .	Stands on cliff chiefly of Thanet Sand. 1912.
6799	Reculvers	Roman wall chiefly of flints built on Thanet Sands. 1912.
6800	Reculvers	Marsh occupying site of channel which formerly divided Thanet from the mainland. 1912.
6801	Near Reculvers . . .	Ledge formed of top beds of Thanet Sands. 1912.
6802	Toy's Hill, near Sundridge . .	Chert quarry in Hythe beds. 1910.
6803	Manor Farm, Sundridge . .	Anticline in Hythe beds. 1910.
6804	Erith, Parish's Pit . . .	Thanet Sand. 1912.
6805	Erith, Parish's Pit . . .	Woolwich beds on Thanet Sand. 1912.
6806	Erith, Parish's Pit . . .	Thanet Sand with base of Woolwich beds. 1912.
6807	Erith, Parish's Pit . . .	Blackheath pebble beds, near view. 1912.
6808	Erith	Section London Clay to Thanet Sands. 1912.
6809	Erith	Pebbles from Blackheath beds. 1912.
6810	Otford, pit near station . .	Thick layer of chalky rainwash overlying Chalk. 1909.
6811	Otford, pit near station . .	Thick layer of chalky rainwash overlying Chalk. 1909.
6812	Shore Hill, above Kemsing, N. Downs	Lower Greensand ridge and Vale of Holmesdale. 1909.
6813	(vi) Wansunt Pit, Dartford Heath	General view of gravel pit.
6814	Wansunt Pit, Dartford Heath .	Gravel overlying Thanet Sand.
6815	(ii) Wansunt Pit, Dartford Heath	Gravel overlying Thanet Sand. 1913.
6816	(v) Wansunt Pit, Dartford Heath	Detail, gravel overlying Thanet Sand. 1913.
6817	(4) Wansunt Pit, Dartford Heath	Detail, gravel overlying Thanet Sand. 1913.
6818	Bowman's Lodge Pit, Dartford Heath	Crater-like gravel-pit. 1913.
6819	(I) Rutter's Pit, North End, Crayford	Brick-earth Section. 1913.
6820	(II) Norris' Pit, North End, Crayford	Thanet Sand overlain by re-deposited Tertiary material not yet quite brick-earth. 1913.
6821	(IV) Norris' Pit, North End, Crayford	Thanet Sand overlain by re-deposited Tertiary material not yet quite brick-earth. 1913.

6822	(III) Furner's Pit, Slades Green, Crayford	False-bedded sand below brick-earth. 1913.
6823	Swanscombe	Hill-creep in Thanet beds. 1908.
6824	Swanscombe	Hill-creep in ?Thanet beds. 1908.
6825	Swanscombe	Piped surface of Chalk. 1908.
6826	Swanscombe, Milton Street Gravel Pits	Probing gravel for Palæolithic implements. 1908.
6827	Borstal Manor Pit . . .	Upper Chalk Section. 1912.
6828	Peters' Pits, Wouldham . .	Section *R. cuvieri* to *S. varians*. 1912.
6829	Peters' Pits, Wouldham . .	Chalk Section, *A. plena* to *S. varians*. 1912.
6830	Peters' Pits, Wouldham . .	*H. subglobosus* chalk faulted against *S. varians* level. 1912.
6831	Peters' Pits, Wouldham . .	*H. subglobosus* chalk. 1912.
6832	Peters' Pits, Wouldham . .	*H. subglobosus* chalk. 1912.
6833	Tonbridge	View across Weald Clay valley to N. Downs. 1913.
6834	Tonbridge	Ashdown Sand (on right) thrust over Wadhurst Clay (on left). 1913.
6835	Tonbridge, Quarry Hill Brickworks	Section of Wadhurst Clay. 1913.
6836	Tonbridge, Quarry Hill Brickworks	Bits of *Equisetum* in Wadhurst Clay. 1913.
6837	High Brooms, near Tunbridge Wells	Tunbridge Wells Sand on Wadhurst Clay. 1913.
6838	High Brooms, near Tunbridge Wells	Tunbridge Wells Sand on Wadhurst Clay. 1913.
6839	Fox's Hole, Rusthall Common, Tunbridge Wells	Master joint in Tunbridge Wells Sand. 1909.
6840	Rusthall Common, Tunbridge Wells	Worm-cast in ripple-marked Tunbridge Wells Sand. 1909.
6841	Rusthall Common, Tunbridge Wells	Erosion along bedding and joint planes in Tunbridge Wells Sand. 1909.
6842	(12) Rusthall Common, Tunbridge Wells	Weathering of Tunbridge Wells Sand. 1909.
6843	(8) Parson's Head, Rusthall Common, Tunbridge Wells	'Land-stack' of thick-bedded Upper Tunbridge Wells Sand. 1909.
6844	(9) Toad Rock, Rusthall Common, Tunbridge Wells	Formed by ? wind erosion along joints and bedding planes in Upper Tunbridge Wells Sand. 1909.
6845	(15) Waterloo Rocks, Tunbridge Wells Common	Rows of holes in Tunbridge Wells Sand due to percolating water. 1909.

Photographed by Amos, 12 *Margate Street, Dover.* 1/2.

6846	Fan Bay, Dover . . .	Chalk zones, *M. coranguinum* to *T. gracilis*.
6847	Fan Bay, Dover . . .	Chalk zones and characteristic vertical cliff.
6848	Between Fan Bay and S. Foreland	Chalk zones, *M. coranguinum* to *H. planus*.
6849	Hope or Leathercoat Point, Dover	Chalk cliff with flints and thin turf-covered soil.
6850	Hope or Leathercoat Point, Dover	Shore platform, shingle beach, and chalk cliffs.
6851	The Warren, Folkestone, looking W.	Chalk cliffs overlooking undercliff of Gault and slipped Chalk.
6852	The Warren, Folkestone, looking E.	Chalk cliffs overlooking undercliff of Gault and slipped Chalk.

Leicestershire.—*Photographed by the late* T. W. Reader *and presented by* F. W. Reader. 1/4.

6853	Kinckley Old Quarry, Swithland Reservoir	Mélange of granite, pegmatite, quartz-mica-diorite, and felsite. 1912.

6854	Brazil Wood, Swithland Reservoir	Slickensided schist at junction of Charnian and igneous intrusion. 1912.
6855	Brazil Wood, Swithland Reservoir	Contorted Charnian rocks (?Brand) with intrusive quartz-mica-diorite. 1912.
6856	(1) Bardon Hill, Main Quarry .	Trias resting on Bardon 'Porphyroid.'
6857	(2) Bardon Hill, Main Quarry .	Trias resting on Bardon 'Porphyroid.'
6858	(4) Bardon Hill, Siberia Quarry .	Bardon 'Porphyroid.'
6859	(6) Bardon Hill, Main Quarry .	Trias resting on Bardon 'Porphyroid.'
6860	(9) Timberwood, Charnwood .	Altered felsitic agglomerate.
6861	(10) Timberwood, Charnwood .	Altered felsitic agglomerate.
6862	(11) Timberwood, Charnwood .	Altered felsitic agglomerate.
6863	Mount Sorrel Granite Quarry .	Trias capped by glacial beds overlying jointed granite. 1912.
6864	Mount Sorrel	The Soar Valley in flood. 1912.
6865	Mount Sorrel Granite Quarry .	Basic dyke in granite. 1912.
6866	Mount Sorrel Granite Quarry .	Trias resting on granite, also blasting. 1912.
6867	Mount Sorrel Granite Quarry .	Trias resting on granite. 1912.
6868	Mount Sorrel Granite Quarry .	Trias resting on granite. 1912.

MIDDLESEX.—*Photographed by the late* T. W. READER *and presented by* F. W. READER. 1/4.

6869	Harefield	'Pipes' in chalk filled with gravel. 1913.
6870	Harefield	'Pipes' in chalk filled with gravel. 1913.
6871	Harefield	'Pipes' in chalk filled with gravel. 1913.
6872	Harefield	'Pipes' in chalk filled with gravel. 1913.
6873	Harefield	'Pipes' in chalk filled with gravel. 1913.
6874	Harefield	Bored top of chalk below Reading beds. 1913.

NORFOLK.—*Photographed by* S. H. REYNOLDS, M.A., Sc.D., *The University, Bristol.* 1/4.

6875	(23·45) W. of Mundesley . .	Cromer Forest bed. 1923.
6876	(23·47) W. of Mundesley . .	Folded Cromer till. 1923.
6877	(23·46) Sidestrand, foreshore .	Contorted Cromer till. 1923.
6878	(23·49) Sidestrand, foreshore .	Contorted Cromer till. 1923.
6879	(23·48) E. from site of Sidestrand Church	Finely laminated till,? englacial. 1923.
6880	(23·51) W. of Overstrand . .	Contorted drift. 1923.
6881	(23·52) Overstrand . . .	Old groynes and present coastline. 1923.
6882	(23·50) Overstrand . . .	Groyne showing south-eastward drift of shingle. 1923.
6883	(23·53) Cromer	Groyne showing south-eastward drift of shingle. 1923.
6884	(23·54) W. of West Runton .	Boulder clay cliffs. 1923.
6885	(23·56) Runton	Paramoudras on shore. 1923.
6886	(23·57) Shore, W. Runton . .	Flint circle surrounding paramoudra. 1923.
6887	(23·58) Shore, W. Runton . .	Paramoudra. 1923.
6888	(23·59) Near Upper Sheringham .	Cromer moraine country. 1923.
6889	(23·60) Holt Station . . .	Cannon-shot gravel. 1923.
6890	(23·61) Weybourn . . .	Rearranged chalky drift with wisps of sand. 1923.
6891	(23·62) Weybourn . . .	Weybourn Crag on Chalk with drift above. 1923.
6892	(23·63) Sheringham . . .	Groynes. 1923.
6893	(23·64) Shore E. of Sheringham .	Concentric flint masses. 1923.
6894	(23·65) E. of Sheringham . .	Weybourn Crag on brecciated Chalk. 1923.
6895	(23·66) E. of Sheringham . .	Boulder Clay cliffs. 1923.

6896	(23·67) Sprowston, Norwich .	Norwich brick-earth, overlain by 'Middle' glacial sands and gravels, capped by cannon-shot gravel. 1923.
6897	(23·68) Sprowston, Norwich .	Mid-glacial sands and gravel. 1923.
6898	(23·69) Sprowston, Norwich .	Mid-glacial sands and gravel. 1923.
6899	(23·70) Sprowston, Norwich .	Mid-glacial sands and gravel. 1923.
6900	(23·76) Eaton, Norwich . .	Norwich Crag on Chalk. 1923.

Photographed by A. L. Leach, *Giltar, Shrewsbury Lane, Woolwich, S.E.* 18. 1/4.

6901	Cliffs between W. Runton and Cromer	Boulder of chalk in the Contorted Drift. 1923.
6902	Shore between Cromer and West Runton	Ring of flints enclosing 'paramoudra.' 1923.
6903	Shore between Cromer and West Runton	Group of paramoudras. 1923.
6904	Mundesley	Forest Bed with driftwood stump. 1923.
6905	Cliffs near Mundesley . .	Isoclinal folds in glacial clay and sand. 1921.

Oxfordshire.—*Photographed by the late* T. W. Reader *and presented by* F. W. Reader. 1/4.

6906	Span Hill, Sonning . . .	Quarry in chalk (*M. coranguinum* zone). 1910.
6907	Span Hill, Sonning . . .	Flints in Upper Chalk (*M. coranguinum* zone). 1910.
6908	Span Hill, Sonning . . .	Flints in Upper Chalk. 1910.
6909	Span Hill, Sonning . . .	Flints in Upper Chalk. 1910.
6910	Span Hill, Sonning . . .	Flints in Upper Chalk (*M. coranguinum* zone). 1910.
6911	'The Flowing Spring,' Span Hill, Sonning	Breaking out where the chalk hills met the Thames flood plain. 1910.
6912	(A) Near foot of Watlington Hill .	Nodular chalk, zone of *R. cuvieri*. 1912.
6913	(B) Near foot of Watlington Hill .	Marly chalk, zone of *H. subglobosus*. 1912.
6914	(C) Near foot of Watlington Hill .	'Doubled' joints in *H. subglobosus* chalk. 1912.
6915	(G) Road cutting below Hollandridge, ½ mile N. of Pishill	Irregular seams of double tabular flint.

Shropshire.—*Photographed by the late* T. W. Reader *and presented by* F. W. Reader. 1/4.

6916	Presthope, Wenlock Edge . .	Wenlock Limestone Quarry.
6917	Presthope, Wenlock Edge . .	Wenlock Limestone Quarry.
6918	Presthope, Wenlock Edge . .	Wenlock Limestone Quarry.
6919	Presthope, Wenlock Edge . .	Wenlock Limestone Quarry.
6920	Presthope, Wenlock Edge . .	Wenlock Limestone Quarry.
6921	Presthope, Wenlock Edge . .	Wenlock Limestone Quarry.
6922	Presthope, Wenlock Edge . .	Wenlock Limestone Quarry.

Photographed by S. H. Reynolds, M.A., Sc.D., *The University, Bristol.* 1/4.

6923	(26·1) Overley Hill nr. Wellington	Banded rhyolite. 1926.
6924	(26·2) Lawrence Hill Quarry, Wrekin	Basic dyke in Precambrian tuff. 1926.
6925	(26·3) Lawrence Hill Quarry, Wrekin	Bedding planes (?) in Precambrian tuff. 1926.
6926	(26·4) Nills Hill Quarry, Habberley, near Pontesbury	Highly inclined Arenig quartzite. 1926.

6927	(26·5) Caer Caradoc and the Lawley from Cardingmill	Uriconian Hills. 1926.
6928	(26·6) W. face of Caer Caradoc .	Steep descent to line of Stretton fault. 1926.
6929	(26·8) Top of Caer Caradoc . .	Crags of Uriconian rhyolite. 1926.

SOMERSET.—*Photographed by the late* T. W. READER *and presented by* F. W. READER. 1/4.

6930	Portishead, shore W. of the pier .	Carboniferous Limestone highly disturbed by overthrust. 1919.
6931	Portishead, shore S. of Woodhill Bay	False-bedded O.R.S. 1919.
6932	Portishead, shore S. of Woodhill Bay	Cornstone in O.R.S. 1919.
6933	Portishead, shore S. of Woodhill Bay	Cornstone in false-bedded O.R.S. 1919.
6934	Portishead, shore S. of Battery Point	Syncline in K_2 beds. 1919.
6935	Portishead, shore S. of Battery Point	Anticline in K_2 beds. 1919.
6936	Portishead, shore S. of Battery Point	Anticline in K_2 beds. 1919.
6937	Portishead, shore S. of Woodhill Bay	Unconformity, Trias Conglomerate on O.R.S. 1919.
6938	Cheddar	Cliffs on scarp (S.E.) side of gorge. 1919.
6939	Cheddar	Contrast between scarp side and dip slope side of gorge. 1919.
6940	Cheddar	Cliffs on scarp (S.E.) side of gorge. 1919.
6941	Burrington Combe, 'Rock of Ages'	Solution 'cleft' in S_1. 1919.
6942	Burrington Combe . . .	Water-sink, W. twin stream. 1919.
6943	Burrington Combe . . .	Water-sink, W. twin stream. 1919.
6944	Spring Cove, Weston-super-Mare	Raised beach on Carboniferous Limestone (C beds). 1919.
6945	Spring Cove, Weston-super-Mare	Lava flow with over- and under-lying Carboniferous Limestone (C_1 beds). 1919.
6946	Woodspring, W. exposure . .	The lava flow. 1919.
6947	Woodspring, W. exposure . .	Lava flow and underlying limestones and tuffs. 1919.
6948	Woodspring, W. exposure . .	Top of volcanic series and base of *laminosa* dolomite. 1919.
6949	Woodspring, W. exposure . .	Upper part of volcanic series and base of *laminosa* dolomite. 1919.
6950	Woodspring, W. exposure . .	Veined and weathered tuff. 1919.
6951	Woodspring, W. exposure . .	Top of volcanic series and base of *laminosa* dolomite. 1919.
6952	Woodspring, '2nd exposure' .	Top of volcanic series and base of *laminosa* dolomite. 1919.
6953	Woodspring, '2nd exposure' .	Top of volcanic series and base of *laminosa* dolomite. 1919.
6954	Avon Section, left, 3rd quarry .	*Caninia* dolomite on *Caninia* oolite. 1919.
6955	(a) Radstock Grove Quarry .	Lias—Hettangian to Charmouthian. 1919.
6956	(B) Bowldish Quarry, N. of Welton	White Lias to *Bucklandi* beds. 1919.
6957	(1) Bowldish Quarry, N. of Welton	White Lias and base of *planorbis* beds. 1919.
6958	(2) Bowldish Quarry, N. of Welton	*Bucklandi* beds. 1919.
6959	(3) Clandown Colliery Quarry, Radstock	*Jamesoni* to *planorbis* beds. 1919.
6960	(4) Clandown Colliery Quarry, Radstock	L. Lias—Charmouthian to Hettangian. 1919.
6961	(5) Grove Quarry, Radstock .	*Jamesoni* beds to White Lias. 1919.
6962	(6) Grove Quarry, Radstock .	*Angulatus* beds to White Lias. 1919.
6963	(7) Grove Quarry, Radstock .	Charmouthian to White Lias. 1919.

6964	(8) Grove Quarry, Radstock .	*Angulatus* and *planorbis* beds. 1919.
6965	(9) Grove Quarry, Radstock .	White Lias. 1919.
6966	(10) Grove Quarry, Radstock .	White Lias and *planorbis* beds. 1919.
6967	Blue Anchor Point, near Watchet	Gypsiferous Upper Keuper marls. 1913.
6968	Blue Anchor Point, near Watchet	Upper Keuper marl.
6969	Blue Anchor Point, near Watchet	Keuper marls with veins of gypsum. 1913
6970	Blue Anchor Point, near Watchet	Gypsiferous Upper Keuper marls. 1913
6971	Near Blue Anchor Point . .	Disturbed Upper Keuper marl.
6972	Warren Farm, near Watchet .	Disturbed Upper Keuper marl. 1913.
6973	Warren Farm Section, Cleeve Bay, Watchet	Disturbed Upper Keuper marl.
6974	Lilstock Bay, near Watchet .	Cliffs chiefly of Upper Keuper marl and Rhætic. 1914.
6975	Lilstock, near Watchet . .	Section Lower Lias to Lilstock beds. 1914.
6976	Lilstock, near Watchet . .	Section Lower Lias to Keuper. 1914.
6977	Lilstock Bay, near Watchet	Cliffs chiefly of Upper Keuper marl and Rhætic. 1914.
6978	Moolham, near Ilminster	Upper Lias on Marlstone.
6979	Montacute	Hills of Yeovil Sands in which Ham Hill stone is developed.
6980	St. Michael's Hill, Montacute .	Upper part of hill mainly Yeovil Sands, lower part Upper and Middle Lias.
6981	Ham Hill, near Montacute .	Quarry in Ham Hill stone. 1911.
6982	Ham Hill, near Montacute .	Quarry in Ham Hill stone. 1911.
6983	Ham Hill, near Montacute .	Quarry in Ham Hill stone. 1911.
6984	Stoford Quarry, near Yeovil .	Fuller's Earth merging into Inferior Oolite.
6985	Stoford, near Barwick . .	Yeovil Sands and sandrock. 1911.
6986	Stoford Quarry, near Yeovil .	Fuller's Earth merging into Inferior Oolite.
6987	Snowdon Hill Quarry, near Chard	Upper Greensand. 1911.
6988	Snowdon Hill Quarry, near Chard	Disturbed Chalk faulted against U.G.S. 1911
6989	Snowdon Hill Quarry, near Chard	Disturbed Chalk faulted against U.G.S. 1911.
6990	Snowdon Hill Quarry, near Chard	Chalk faulted against Upper Greensand. 1911.
6991	Snowdon Hill Quarry, near Chard	Upper Greensand overlain by Chalk. 1911.
6992	Puriton	White Lias overlain by *tatei* to *planorbis* beds.
6993	Puriton Manor, near Dunball .	Cores of boring.
6994	Hestercombe, near Taunton .	Morte Slates. 1911.
6995	Hestercombe, near Taunton .	Morte Slates. 1911.
6996	Hestercombe, near Taunton .	Quarry in Morte Slates and diorite. 1911.

Photographed by R. H. Coysh, 16 *Belluton Road, Knowle, Bristol.* 1/4.

6997	(6) Read's Cave, Burrington .	The eastern swallet. 1919.

Photographed by J. H. Savory, *Abbot's Leigh, near Bristol.* 1/1 *and* 1/2

6998	(1) Swildon's Hole, near Priddy .	Contorted limestone. 1921. 1/1.
6999	(2) Swildon's Hole, near Priddy .	Stalactites, 'Barnes' Loop.' 1921. 1/1.
7000	(3) Swildon's Hole, near Priddy .	Stalagmite, 'the White Way.' 1921. 1/1.
7001	(4) Swildon's Hole, near Priddy .	Slender stalagmite pillars. 1921. 1/2.
7002	(5) Swildon's Hole, near Priddy .	Stalactites and stalagmites. 1922. 1/2.
7003	(6) Swildon's Hole, near Priddy .	Stalagmite, 'Barnes' Loop.' 1922. 1/2.
7004	(7) Read's Cavern, Burrington .	Fallen blocks on floor of cave and highly inclined limestone forming rear wall. 1921. 1/2.

Photographed by F. G. JENKINS, 6 *Brandon Villas, Park Street, Bristol.* 1/4.

7005	( ) Burrington . . .	Swallet, entrance to Read's Cavern. 1919.

Photographed by J. W. TUTCHER, 57 *Berkeley Road, Bishopston, Bristol.* 1/2.

7006	(F) Near Fillwood Farm, 2½ miles S. of Bristol Bridge	Lower Lias—*Ostrea, planorbis,* and *Johnstoni* beds. 1912.
7007	(G) Keeling's Limeworks, Keynsham	Upper and Lower *Bucklandi* beds. 1923.
7008	(H) Charlton Road, Keynsham .	*Bucklandi* limestone succeeded by *semicostatus* clay. 1902.
7009	(L) Railway cutting, Kelston Station	Base of Lower Lias (Hettangian). 1902.
7010	(11) Hodder's Quarry, Timsbury	*Turneri* clays and *obtusum* beds. 1911.
7011	(13) Tyning Colliery Quarry, Radstock	Section *striatum* clay to White Lias. 1911.
7012	(12) Wellsway Quarry, Radstock	*Planorbis* and *angulatus* beds. 1910.

Photographed by S. H. REYNOLDS, *M.A., Sc.D., The University, Bristol.* 1/4.

7013	(24·20) Cheddar Gorge . .	Looking down (S.) from above gorge on W. side. 1920.
7014	(22·24) Cheddar . . .	Scarp side of gorge. 1924.
7015	(23·24) Cheddar . . .	Scarp side of gorge. 1924.

STAFFORDSHIRE.—*Photographed by* C. S. GARNETT, 25 *Crompton Street, Derby.* 1/4.

7016	(10) Winshill, Burton-on-Trent .	Veins of fibrous gypsum in Keuper marl. 1921.
7017	(11) Winshill, Burton-on-Trent .	Veins of fibrous gypsum in Keuper marl. 1921.
7018	(12) Winshill, Burton-on-Trent .	Veins of fibrous gypsum in Keuper marl. 1921.
7019	(13) River Manifold, near Ashbourne	River-bed dry in summer. 1921.

SUFFOLK.—*Photographed by the late* T. W. READER *and presented by* F. W. READER. 1/4.

7020	(1) Sudbury, Green's Pit, Acton Road	Contorted gravel, sand, silt, and redeposited Chalk. 1910.
7021	(2) Sudbury, Gallows' Hill Pit .	Undisturbed sandy silt passing up into boulder clay. 1910.
7022	(3) Sudbury, Gallows' Hill Pit .	Boulder clay filling depression in glacial sandy silt. 1910.
7023	(4) Sudbury, Gallows' Hill Pit .	Boulder clay filling depression in glacial sandy silt. 1910.
7024	(5) Sudbury, probably Victoria Pits	Gravel and sand, on Crag, on Thanet Sand on Chalk. 1910.
7025	(6) Sudbury, probably Victoria Pits	Boulder clay overlying gravel and rhythmically banded silt. 1910.
7026	(7) Sudbury, probably Alexandra pits	Boulder clay on undisturbed bedded sands. 1910.
7027	(8) Sudbury, Alexandra Pits .	Boulder clay extending into hollow in bedded sands. 1910.
7028	(9) Sudbury, Whorlow's Chalk Pit	Gravel, on Crag, on Thanet Sand on Chalk. 1910.
7029	(10) Sudbury, probably Station Pit	Gravel, on Crag, on Thanet Sand on Chalk. 1910.
7030	(1) Sudbury, Little Cornard Brick Pit	Mass of re-made Chalk, boulder in clay. 1913.

7031	(5) Ballingdon Hill Sand Pit, Sudbury	Faulted glacial sand overlain by boulder clay. 1913.
7032	(6) Sudbury, Ballingdon Hill Sand Pit	Bedded sand with overlying boulder clay. 1913.
7033	(16) Sudbury, Ballingdon Grove Pit	Striated stone. 1913.
7034	Sudbury, Ballingdon Grove Pit .	Irregular junction between gravel and overlying decalcified boulder clay, 1913.
7035	Pit near Whitehorse Farm, 1 mile E. of Bentley Church	Current-bedded shelly Red Crag. 1913.
7036	Pit near Whitehorse Inn, 1 mile E. of Bentley Church	Current-bedded shelly Red Crag. 1913.
7037	(6) ?Pit near Rookery Farm, Bentley	Red Crag. 1913.
7038	(2) Pit 300 yards E. of Bentley Station	Shelly Newbournian Red Crag. 1913.
7039	(7) ?Pit near Rookery Farm, Bentley	Red Crag. 1913.
7040	Tattingstone Hall Farm . .	Shelly Red Crag overlying Coralline Crag. 1913.

SURREY.—*Photographed by the late* T. W. READER *and presented by* F. W. READER. 1/4.

7041	Marden Park, N. Downs . .	Blackheath pebble beds. 1914.
7042	Marden Park, N. Downs . .	Blackheath pebble beds on Lower Chalk. 1914.
7043	Marden Park, N. Downs . .	Detail Blackheath pebble beds. 1914.
7044	Nonsuch Farm, Ewell . .	Slickensided chalk. 1912.
7045	Nonsuch Farm, Ewell . .	Slickensided joint-plane. 1912.
7046	Nonsuch Farm, Ewell . .	Slickensided joint-plane. 1912.
7047	Nonsuch Kiln	Reading Beds. 1912.
7048	Nonsuch Kiln	Reading Beds. 1912.
7049	Nonsuch Kiln	Reading Beds. 1912.
7050	Lower Cheam	Basement bed of London Clay with *Ostrea*. 1912.
7051	Godstone, Horse Shaw . .	'Scarp drift' on Upper Greensand. 1916.
7052	Godstone, Horse Shaw . .	'Scarp drift' on Upper Greensand. 1916.
7053	Headley, Bishop's Chalk Pit, Ashtead Park	Upper Chalk, zones of *Marsupites* and *M. coranguinum*. 1916.
7054	Headley Heath	Gravel (? glacial). 1916.
7055	Headley Heath	Gravel (? glacial) showing flint pebbles on end. 1916.
7056	Godstone, near Quarry Farm .	'Scarp Drift' on Upper Greensand. 1916.
7057	Godstone, Quarry Farm Pit .	Open working in Upper Greensand. 1916.
7058	Raikes' Hollow, Abinger . .	Section Bargate Beds. 1903.
7059	Raikes' Hollow, Abinger . .	Section Bargate Beds. 1903.
7060	Farnham	Gravel terrace, S. side of R. Wey.
7061	(4) Farnham, Wilkinson's Pit, near Boundstone P.O.	'Alice Holt' gravel plateau.
7062	(2) Farnham Terrace, S. side R. Wey	Gravels with palæoliths overlain by brick-earth.
7063	(1) Tilburstow Hill . . .	Steeply dipping Hythe beds. 1915.
7064	(2) Tilburstow Hill . . .	Steeply dipping Hythe beds. 1915.
7065	Plantation Pits, 1 mile W. of Tilburstow Hill	Hythe beds, glauconitic sandstone on chert. 1915.
7066	(4) Plantation Pits, 1 mile W. of Tilburstow Hill	Cherty Hythe beds. 1915.
7067	(5) Church Quarry, Nutfield .	Lower Greensand section with Fuller's Earth seam. 1915.
7068	(7) Church Quarry, Nutfield .	Lower Greensand section with ?Pleistocene erosion channel in upper beds. 1915.

7069	(8) Church Quarry, Nutfield .	Fuller's Earth seam in Lower Greensand. 1915.
7070	(9) Plantation Pits, Tilburstow Hill	Dip slope of Lower Greensand. 1915.
7071	(10) Looking S. from Tilburstow Hill	Weald Plain. 1915.
7072	Worms Heath, $1\frac{1}{4}$ mile S.E. of Upper Warlingham	Blackheath pebble beds. 1910.
7073	Worms Heath, $1\frac{1}{4}$ mile S.E. of Upper Warlingham	Blackheath pebble beds. 1910.
7074	Worms Heath, $1\frac{1}{4}$ mile S.E. of Upper Warlingham	Pinnacle of Chalk projecting through Blackheath Beds. 1910.
7075	Worms Heath, $1\frac{1}{4}$ mile S.E. of Upper Warlingham	Mass of Chalk projecting into Blackheath Beds. 1910.
7076	Worms Heath, $1\frac{1}{4}$ mile S.E. of Upper Warlingham	Blackheath Beds resting on very irregular surface of Chalk. 1910.

SUSSEX.—*Photographed by the late* T. W. READER *and presented by* F. W. READER. 1/4.

7077	High Rocks, Tunbridge Wells .	Honeycomb weathering in Upper Tunbridge Wells sand. 1909.
7078	High Rocks, Tunbridge Wells .	Honeycomb weathering in Upper Tunbridge Wells sand. 1909.
7079	High Rocks, Tunbridge Wells .	Joint fissure enlarged by weathering in Upper Tunbridge Wells sand. 1909.
7080	High Rocks, Tunbridge Wells .	Vertical joints enlarged by weathering in Upper Tunbridge Wells sand. 1909.
7081	High Rocks, Tunbridge Wells .	Joint fissure enlarged by weathering in Upper Tunbridge Wells sand. 1909.
7082	High Rocks, Tunbridge Wells .	Joint enlarged by weathering in current-bedded Upper Tunbridge Wells sand. 1909.
7083	High Rocks, Tunbridge Wells .	Undercutting ? by wind of Upper Tunbridge Wells sand. 1909.
7084	Rottingdean	Cliffs of *Actinocamax quadratus* chalk. 1909.
7085	Rottingdean	Cliffs of *Actinocamax quadratus* chalk. 1909.

WILTSHIRE.—*Photographed by the late* T. W. READER *and presented by* F. W. READER. 1/4.

7086	Dead Maid Quarry, Mere . .	Lower Chalk on Upper Greensand. 1916.
7087	Dead Maid Quarry, Mere . .	Lower Chalk on Upper Greensand. 1916.
7088	Mere, Dead Maid Quarry . .	Block of spicule-bearing chert. 1916.
7089	Charnage Hill, Mere . . .	Middle Chalk with base of Upper Chalk. 1916.
7090	Charnage Hill, Mere . . .	Middle Chalk with base of Upper Chalk. 1916.
7091	Baycliffe Quarry, 1 mile N.E. of Maiden Bradley.	Upper beds of Upper Greensand. 1916.
7092	Baycliffe Quarry, 1 mile N.E. of Maiden Bradley	Detail upper beds of Upper Greensand. 1916.
7093	Maiden Bradley . . .	Section Cenomanian and Selbornian. 1916.
7094	Search Farm, Stourton, lower pit .	Base of Chalk Marl with Chloritic Marl overlying 'cornstone' below. 1916.
7095	Search Farm, Stourton . .	Chalk Marl with grey chalk at base. 1916.
7096	Search Farm, Stourton . .	Base of Chalk Marl resting on Chloritic Marl with 'cornstone' below. 1916.
7097	Search Farm, Stourton . .	Detail of Chalk Marl. 1916.
7098	View from Search Farm, Stourton	Shows line of big fault. 1916.
7099	Blackhill Quarry, near Longbridge Deverill	Spicule-bearing beds of Upper Greensand. 1916.

7100	Blackhill Quarry, near Longbridge Deverill	Lower part of spicule-bearing beds of Upper Greensand. 1916.
7101	Norton Ferris, Kilmington . .	Junction Lower Chalk and Upper Greensand. 1916.
7102	Norton Farm, Kilmington . .	Junction Lower Chalk and Upper Greensand. 1916.
7103	Crockerton brickyard, S.W. of Warminster	Gault overlain by Malmstone.
7104	Wockley, near Tisbury . .	Lower Purbeck beds. 1911.
7105	Wockley, near Tisbury . .	Lower Purbeck beds. 1911.
7106	Chilmark Ravine . . .	Upper and chalk beds of Portland Stone. 1911.
7107	Teffont side of Chilmark Ravine .	Lower Purbecks on Portlands. 1911.
7108	Teffont side of Chilmark Ravine .	Lower Purbecks on Portlands. 1911.
7109	Chilmark Ravine . . .	Chalky series of Portland beds. 1911.
7110	Teffont Evias (limekiln pit) . .	Junction of Middle and Lower Purbeck, 1911.
7111	Teffont Evias (limekiln pit) . .	Middle and Lower Purbeck. 1911.
7112	Teffont Evias (limekiln pit) . .	Casts of sun-cracks in Middle Purbeck. 1911.

Photographed by J. W. TUTCHER, 57 *Berkeley Road, Bishopston, Bristol.* 1/2.

7113	Westbury Iron Works . .	Corallian rocks and iron ore. 1895.

YORKSHIRE.—*Photographed by the late* T. W. READER *and presented by* F. W. READER. 1/4.

7114	Helwith Bridge, near Horton-in-Ribblesdale	Quarry in Silurian (Horton Flags).
7115	Helwith Bridge, near Horton-in-Ribblesdale	Quarry in Silurian (Horton Flags).
7116	Hunt Pot, near Horton-in-Ribblesdale	In D_2 Limestone.
7117	Hunt Pot, near Horton-in-Ribblesdale	In D_2 Limestone.
7118	Hunt Pot, near Horton-in-Ribblesdale	In D_2 Limestone.
7119	Hunt Pot, near Horton-in-Ribblesdale	In D_2 Limestone.
7120	Thirl or Hull Pot, near Horton-in-Ribblesdale	In D_2 Limestone.
7121	Penyghent	Seen from Horton-in-Ribblesdale Station.
7122	Penyghent	Cap of Millstone Grit, Yoredales below.
7123	Thorns Gill, near Gearstones Inn, Ribblehead	Characteristic beck in Carb. Limestone.
7124	Thorns Gill, near Gearstones Inn, Ribblehead	Characteristic beck in Carb. Limestone.
7125	Thorns Gill, near Gearstones Inn, Ribblehead	Characteristic beck in Carb. Limestone.
7126	Thorns Gill, near Gearstones Inn, Ribblehead	Characteristic beck in Carb. Limestone.
7127	Thorns Gill, near Gearstones Inn, Ribblehead	Mass of Carb. Limestone, probably an erratic.
7128	Giggleswick Scars . . .	The white line marks the position of the S. Craven fault.

Photographed by S. H. REYNOLDS, M.A., Sc.D., *The University, Bristol.* 1/4.

7129	(23·72) Attermire Scars, Settle .	Typical limestone scars. 1923.
7130	(23·73) Attermire Scars, Settle .	Carboniferous Limestone Scenery. 1923.
7131	(23·74) Attermire Scars, Settle .	Carboniferous Limestone Scenery. 1923.
7132	(23·75) Between Attermire and Malham	Limestone plateau with grikes. 1923.

7133	(23·76)	Watersinks, Malham	Stream disappearing on crossing from Silurian on to Carboniferous Limestone. 1923.
7134	(23·77)	Malham Gorge	Dry valley. 1923.
7135	(23·78)	Malham	Dry valley leading to the Cove. 1923.
7136	(23·79)	Malham	Grikes. 1923.
7137	(23·80)	Malham	Grikes. 1923.
7138	(23·81)	Malham	Dry valley leading to the Cove. 1923.
7139	(23·82)	Malham	Outflow of the Aire from Malham Cove. 1923.
7140	(23·83)	Malham	End of dry valley above cove. 1923.
7141	(23·84)	Malham	The Cove from above. 1923.
7142	(23·87)	Malham Cove	1923.
7143	(23·88)	Route Settle to Malham	Contrast, limestone hill on left, grit and shale on right, fault along valley. 1923.
7144	(23·85)	Gordale ravine	Screes. 1923.
7145	(23·86)	Gordale ravine	Screes. 1923.
7146	(23·90)	Norber, near Clapham	Norber boulders. 1923.
7147	(23·91)	Norber, near Clapham	Norber boulders. 1923.
7148	( )	Norber, near Clapham	Norber boulders. 1923.
7149	(23·93)	Norber, near Clapham	Norber boulders. 1923.
7150	(23·94)	Norber, near Clapham	Norber boulders. 1923.
7151	(23·95)	Norber, near Clapham	Norber boulders. 1923.
7152	(23·97)	Norber, near Clapham	Norber boulders. 1923.
7153	(23·98)	Norber, near Clapham	Norber boulders. 1923.
7154	(23·96)	Norber, near Clapham	Norber boulder. 1923.
7155	(23·92)	Norber, near Clapham	Norber boulder. 1923.

Wales.

GLAMORGAN.—*Photographed by* A. L. LEACH, *Giltar, Shrewsbury Lane, Woolwich, S.E.* 18. 1/4.

7156	( )	Gower, Cliffs near the Knave, Paviland	Dip, strike, pre-Triassic platform and scree formation. 1919.

MERIONETH.—*Photographed by* N. G. BLACKWELL *and presented by* A. H. COX. 1/2 *and* 1/4, *and P.C.*

7157	Cader Idris seen from Cyfrwy	General succession. 1/2.
7158	Cader Idris from Gelli-llwyd	Maine escarpment due to granophyre sill. Before 1925. 1/2.
7159	Cader Idris from Llyn-y-gader	Granophyre and dolerite sills. 1/2.
7160	Talylynn Lake, near Dolgelly	Crags of Upper Acid group and granophyre intrusions. Before 1925. 1/4.
7161	Cwm Ammarch, Talylynn, Dolgelly	Stream forming delta. Before 1925. 1/4.
7162	Arthog, looking E. to Craig Llwyd	Cambrian section and intrusive rock. Before 1920. P.C.

PEMBROKESHIRE.—*Photographed by* N. G. BLACKWELL *and presented by* A. H. COX.

7163	Trwyn Ellen, 8 miles E. of Abereiddy	Folded *Lingula* flags. 1/4.
7164	Trwyn Castell, Abereiddy Bay	Rhyolites and Tuffs, Llanrian volcanic series. Before 1915. 1/4.
7165	Abercastle Harbour, looking N.W.	Syncline of *bifidus* shale on ashes. Before 1915. 1/1.
7166	Abercastle Harbour, looking S.E.	On right cliff of *bifidus* shale capped by diabase sill. Before 1915. 1/4.
7167	Aberfelin	Porth Gain beds and *Tetragraptus* shale. Before 1915. 1/4.

Photographed by A. L. LEACH, *Giltar, Shrewsbury Lane, Woolwich, S.E.* 18. 1/4.

7168	Amroth, near Tenby . . .	Block fracturing in Coal Measures determined by bedding planes and joints. 1920.

Scotland.

EDINBURGH.—*Photographed by the late* W. GOODCHILD. 1/2.

7169	Warriston, Canonmills, Edinburgh	Bedded sands and gravels of inner margin of 100 ft. raised beach.

KIRKCUDBRIGHT.—*Photographed by* S. H. REYNOLDS, M.A., Sc.D., *The University, Bristol.* 1/4.

7170	(24·9) S. slopes of Buchan Hill, Loch Trool	Large erratic. 1924.
7171	(24·10) S. slopes of Buchan Hill, Loch Trool	Large erratic. 1924.
7172	(8·24) Loch Valley . . .	Moraine barrier. 1924.

Ireland.

WICKLOW.—*Photographed by* P. B. ROBERTS, 9 *Westbury Hill, Westbury-on-Trym, Bristol.* 1/4.

7173	(23c) Glendalough . . .	Glacial valley in schist, erratics in foreground. 1919.
7174	(18c) Glendalough from upper end	Glaciated valley. 1919.
7175	(26c) Glendalough, lower lake .	Lake lies in depression in moraine material. 1919.
7176	(16c) Glendalough, upper lake .	Lake basin lies in schist just below junction with granite. 1919.
7177	(20c) Lake Nahavagan . .	Cirque lake with granite walls. 1919.
7178	(21c) Lake Nahavagan . .	Cirque lake with granite walls. 1919.
7179	(22c) Above Lake Nahavagan .	Jointed granite. 1919.
7180	(37d) Glenmacanass Falls. .	Drop in glaciated valley from granite on to schist. 1919.

Zoological Bibliography and Publication.—*Report of Committee* (Prof. E. B. POULTON, *Chairman*; Dr. F. A. BATHER, *Secretary*; Dr. W. T. CALMAN, Mr. E. HERON-ALLEN, Dr. P. CHALMERS MITCHELL, Mr. W. L. SCLATER).

SINCE the last meeting of the Association letters have been written and copies of previous Reports sent to Editors of various scientific periodicals, drawing their attention to omissions of desirable information. It is pleasing to note that the recipients are generally grateful.

Arising out of such correspondence, the Science Committee of the Royal Dublin Society has now agreed to put the price and date of issue on a limited number of Authors' Reprints of each paper, and to offer them for sale, thus effecting publication. It is not anticipated that the R. Dublin Society will find any more difficulty in carrying out this useful reform than other societies have found previously.

On January 9 the Secretary addressed the Third Annual Meeting of British Zoologists 'On the importance of writers on zoological subjects following the generally accepted rules of zoological nomenclature and systematic work.' A verbatim report of his remarks was published in *The Naturalist* for March 1926, and has been distributed by the Secretary to the British Zoologists (Professor Balfour Browne). The meeting expressed a wish that Dr. Bather should draw up a more detailed guide to the writing and publication of such zoological work. Much that he would say has already been expressed in the Reports of this Committee, but each new generation needs its own instruction.

Your Committee therefore feels that it is doing a useful work, and asks for its reappointment.

Kent's Cavern, Torquay.—*Report of Committee appointed to co-operate with the Torquay Natural History Society in investigating Kent's Cavern* (Sir A. KEITH, *Chairman*; Prof. J. L. MYRES, *Secretary*; Mr. G. A. GARFITT, Prof. W. J. SOLLAS, Mr. MARK L. SYKES).

WHEN this Committee was appointed, without grant, in September 1925, there was no immediate prospect of excavation in Kent's Cavern. Early in the winter, however, leave was obtained from the proprietor of the Cavern for a preliminary examination of the part known as the ' Vestibule ' ; and an emergency grant of £10 was made by the Council of the British Association, to supplement, if required, the resources of the Torquay Society. Grants of the same amount made by the Royal Society and the Society of Antiquaries are gratefully acknowledged, and also sums placed at the disposal of the Committee through the prompt and friendly help of Mr. Ralph Griffin, F.S.A., from a fund for the employment of ex-Service men. Most of the work of this season, however, has been done voluntarily by members of the Torquay Natural History Society, whose report is appended. To them personally and to their Society for providing work-room and storage in the Torquay Museum, the Committee desires to express its grateful acknowledgment. The Committee asks to be reappointed, with the balance in hand, and renewal of leave to collect funds from other sources as required.

Report on an Excavation in Kent's Hole, Torquay, January-June 1926.

During the winter of 1925 a Committee of the Torquay Natural History Society was formed, to work with a Committee of the British Association, for the purpose of carrying on an excavation in Kent's Hole.

Prof. W. R. Sollas, F.R.S., having visited the Cavern in January 1926, a start was made in the chamber selected by him towards the end of that month. The work has been continued, whenever it has been possible to get a working party together, and the deposits were in a condition to permit of careful sorting, up to the end of June, with short breaks at Easter and Whitsuntide.

The nucleus of the working party has consisted of the undersigned, who have been present throughout the excavations, and desire to acknowledge the occasional and welcome help of Mrs. Dowie, Miss Marjorie Selman, Mr. G. C. Spence, and Mr. W. G. Shannon, M.Sc., F.G.S.

Mr. G. A. Garfitt, F.S.A., a member of the Committee of the British Association, visited Torquay during February, and gave us the pleasure and benefit of his company during six full working days.

The chamber selected for examination was that known as the Vestibule, into which the northern entrance to the cavern leads. At its greatest extent, its dimensions are 40 ft. by 32 ft. It was decided to dig a trench along the entire length of its north wall, from the adjacent east wall to the junction with the adjoining Sloping Chamber. A beginning was made by sinking two pits, some 10 ft. from each other, near the west end of the wall, and a third pit was opened soon after at its east end. In the course of the excavation these pits have been merged into a continuous trench 41 ft. long, which runs from end to end of the north wall, and slightly overlaps into the Sloping Chamber. At its east end it passes under the site of the Magdalenian hearth, discovered by William Pengelly in 1866, and known as the Black Band. A beginning of a trench has also been made along the east wall, in the direction of the entrance.

The depth of the trench varies, according to the nature of the deposit encountered, from 2 ft. 6 in. to 13 ft. Over quite half of the ground the work has been largely of the nature of pure quarrying, owing to the presence, in large numbers, of fallen blocks of limestone of considerable size. The best area has been near the east wall, where a good section has been kept going nearly 4 ft. deep, and has yielded a heavy proportion of the finds.

By the end of June, two sizable areas of crystalline stalagmite had been revealed in the floor of the trench, at each end of it. It is, however, too early to say that these represent portions of an actual stalagmite floor.

So far as it has been physically possible, the deposits have been taken out foot by foot in slices 3 ft. long by 1 ft. broad by 1 ft. in vertical depth. Every find, whether of flints, bones or teeth, has been carefully measured in regard to its depth in the deposit, and entered in a Field Book on the spot, to be subsequently transferred to a Journal.

Fauna.	G.S.	B.B.	C.E. 1′	2′	3′	4′	5′	6′	7′	8′	9′	10′	11′	12′	13′
Horse	×	×	×	×	×	×	×	×	×	×	×	×	×		
Ox	×	×	×	×	×	×	×	×		×		×			
Deer	×	×	×	×	×	×	×	×	×	×			×		
C. Megaceros . . .			×	×	×	×	×		×		×		×		
Reindeer . . .			×	×	×	×	×								
Bear	×	×	×	×	×	×	×	×	×						
Cave Bear			×	×	×	×	×		×						
Rhino. T. . . .	×	×	×	×	×	×	×	×	×	×	×		×		
Elephas prim. . . .			×	×	×	×	×								
Wolf			×	×	×	×	×				×				
Fox	×	×	×	×	×	×	×		×						
Hyæna	×	×	×	×	×	×	×	×	×	×	×	×	×		
Badger		×	×	×	×			×							
Cave Lion				×	×	×	×	×		×					
Flints.															
Type A.				×	×	×		×	×	×		×	×		
,, B.		×	×	×	×	×	×	×	×	×	×		×		

Pengelly's finds 1865/81 throughout the Cavern. (G.S. to 5′)

Finds of February-June, 1926, in Vestibule only. (6′ to 13′)

G.S. = Granular Stalagmite. B.B. = Black Band. C.E.′ = Levels of Cave-Earth.

To these measurements 4 ft. are automatically added to represent the depth of the deposit of cave-earth below the base of the granular stalagmite removed by Pengelly in 1866.

The cave-earth is quite unstratified, and contains abundant angular fragments of limestone, and is, in places, crowded with large blocks fallen from the roof. Rolled pebbles are rare, and of varieties of local stone from the neighbouring hills.

The fauna, so far as it has been identified, is of the same character as that found by Pengelly at higher levels, and no change has been noted, either in the fauna or in the character of the cave-earth itself. (See tabular statement.)

No hearths or workshops have been found, but, scattered here and there, some 135 flints have been recovered. Nearly all are patinated a somewhat dull white. A few have a bluish-white appearance, and rare examples are blackened, probably by decaying vegetation. Omitting waste fragments and small pieces of nuclei, about sixty flints appear to have been implements or broken parts of such, and, with one or two exceptions, they seem to classify into no more than two types: A end-scrapers, and B blades; the latter amounting to about 80 per cent. of the total. These flints now await expert examination at the hands of Prof. Sollas.

Type A. These are 'end-scrapers' of the usual type, with primary flaking along the length of the implement, terminating at the broader end in steep, fanwise retouches, producing a convex scraping edge. The reverse is a flake face, and the implements seem to be in the Aurignacian tradition.

Type B. 'Blades,' with primary flaking along the length of the implement, with either two facets meeting in a carinated median line, or three facets, when the central facet makes a flat ridge. There does not appear to be any retouch along the edges of the blades, which are often equally sharp along each edge. Sometimes, however, the edges are fractured, as if by use. The reverse is a flake face.

It appears, therefore, that we have an industry running almost entirely to the production of simple, unretouched blades. This description seems to apply, with almost equal force, to the implements collected by Pengelly from the higher levels of the cave-earth, and the Black Band.

The absence of bone, horn, and ivory implements suggests that this industry is not typical Magdalenian; of Chatel-perron and Gravette points that it is not a true Aurignacian; of burins that it is neither Aurignacian nor Magdalenian. A few rare specimens have been regarded as Solutrian, but these appear to be intrusions into a culture of a very different type. But the industry is certainly Upper Palæolithic. Pending the results of expert examination it is best, perhaps, to leave it at that.

The period, in time, is limited, at its upper end, by the discoveries made by Pengelly of harpoons of Magdalenian 5, 6, and 6 b respectively in the second and first foot levels of the cave-earth, and in the Black Band. Below these levels, judging by the fauna, the abundance of remains of the horse indicates a steppe climate suggestive of the Aurignacian and Solutrian periods (Achen retreat of the ice) of S. France, but reaching England somewhat later. If may therefore be that 'the knife-blade' industry of Kent's Hole was contemporary in time, however dissimilar in character, with some part of the Solutrian and Magdalenian periods of the Dordogne. The study of the fauna further suggests that the cave-earth was in process of formation at the time when the upper part of the base level and the lower middle levels were being laid down in Mother Grundy's Parlour at Creswell; the upper middle level roughly corresponding to the Black Band. The deposits recently examined at Aveline's Hole in the Mendips seem to correspond to the granular stalagmite of Kent's Hole. Although the Creswell flints are very different from ours, an expert comparison of the material from all three caves seems desirable and might well lead to interesting results.

Sir Arthur Keith, F.R.S., reporting on a skull found in a crevice outside the Vestibule last September, finds a close resemblance between the palate and teeth and those of the human jaw found in the granular stalagmite in Kent's Hole. The skull is brachycephalic, and compares closely with two brachycephalic skulls found at Aveline's Hole, where, also, a good proportion of the flints seem to have been simple, unretouched blades.

We are happy to report that relations with Mr. Powe, the proprietor of the Cavern, have been increasingly amicable; that the total cost of the excavation to date has not exceeded £15; and that it has been unnecessary, as yet, to apply for any portion of the grants provided by the British Association and other learned societies.—F. Beynon, Arthur H. Ogilvie, H. G. Dowie.

Culture of the Peasant Population of Modern Egypt.—*Report of Committee* (Prof. J. L. Myres, *Chairman*; L. H. Dudley Buxton, *Secretary*; Mr. H. Balfour, Mr. E. N. Fallaize, Capt. Hilton Simpson, Prof. H. J. Rose).

The Committee has received the following interim report from Miss Winifred S. Blackman, who has been enabled by grants from the Royal Society and from the Percy Sladen Trustees to spend the greater part of the past season in the Fayum province of Egypt.

While Miss Blackman has received much encouragement and valuable help from Egyptian officials and private individuals, the Committee regrets that the Association's efforts to obtain support for her work from the Egyptian Government have hitherto been without result.

Report from Miss Winifred S. Blackman.

During this season in Egypt I have confined my work almost entirely to Fayum province, as funds were not large enough to admit of my travelling further south. This province also is a profitable one for my work. It is off the beaten track, and therefore the customs among the *fellāhīn* are very primitive. I have made my headquarters in the town of Fayum, which is a good centre from whence I have visited most of the province.

The Under-Secretary of State, to whom the Oriental Secretary, Mr. Furness, gave me an introduction, was most kind, and communicated with the officials in Fayum, telling them to see that I had suitable accommodation there. The Inspector of State Buildings, Selīm Bey, kindly lent me his Rest House in Fayum, where I have stayed most of the time.

I have continued my studies of the customs, industries, &c., of the *fellāhīn*, and have added considerably to the information I have gained in previous years. I think I have now collected sufficient material for my book on Coptic Saints and Muslim Sheikhs and the customs and beliefs connected with these highly venerated saints. Most of these customs and beliefs are direct survivals from those associated with the local gods of ancient times. I hope to get this book completed this year.

I have made a further study of pottery-making, and, though I have not come across different methods from those I have studied in previous years, I have seen different implements used in the manufacture of some of the vessels, and I have collected them and am bringing them with me to England; also samples of the clay, &c., used for the different pots.

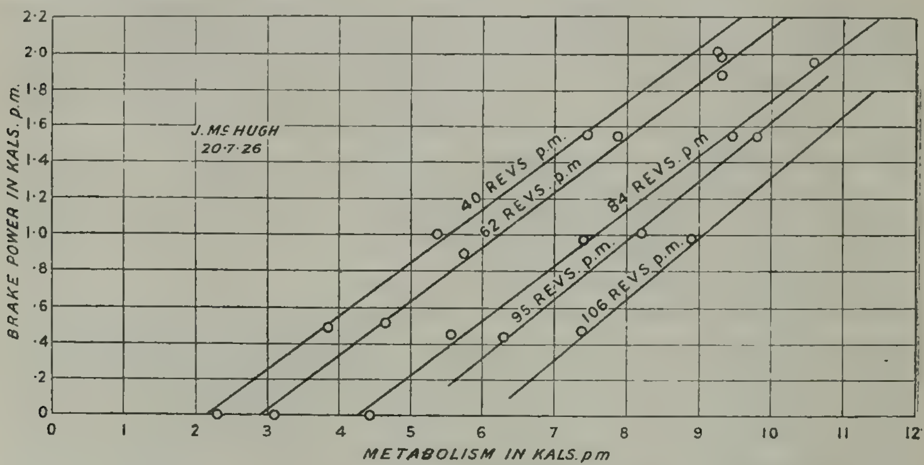
I have collected a number of superstitions and charms from among the *fellāhīn*, especially from the women, and also primitive medical cures.

I have obtained more information on the belief in 'the double'—a belief which is deeply rooted and widely spread all over this country. I have also studied the belief about the *ukht*, which one or two authorities have thought was the same as the *karīn* (or double). I have found that it is a quite distinct personality, and this should help to throw light on the whole question of the *karīn*, which has hitherto been somewhat confused. I have witnessed and photographed two or three fertility rites which I have not seen before, and obtained more information on Sheikh possession and other beliefs.

I have taken a large number of photographs of industries and ceremonies, as well as of the scenery of this province, which varies very much. It is work which must be done very slowly if it is to be accurate, and there is any amount more to be done. All the local differences must be studied, and the oases and Lower Nubia should be included in the area. I have many more years of work ahead, if only I can obtain sufficient financial assistance.

Cost of Cycling at Varied Rate and Work.—*Report of Committee* (Prof. J. S. MACDONALD, *Chairman* ; Dr. F. A. DUFFIELD, *Secretary*). (*Drawn up by the Secretary.*)

THE intention in this set of experiments was to obtain data covering a greater range of movement than had hitherto been attempted, and consequently the subject of heavier weight and stronger build (J. McH.) was selected to perform the cycling involving additional endurance at these faster rates. The procedure followed in these experiments was precisely the same as that employed in the former work. The subject pedalled on a stationary bicycle with a rope-brake acting on the hind wheel. The levels of work were approximately 0, ·5, 1·0, 1·5, and 2·0 kals. per minute. The new rates of cycling were at 95 and 106 revolutions a minute. Samples of expired air were collected at 18, 23, and 28 minute intervals respectively after the commencement of the cycling, and the mean of the three air analyses is taken and expressed as kalories per minute.



The fresh data are plotted on the accompanying chart, alongside those of the lower rates of 40, 62, and 84 revolutions a minute, thus providing a series of metabolic values resulting from the performance of varying amounts of work at five different rates of movement. The experimental points obtained from the faster rates—namely, 95 and 106 revolutions per minute, lie on two straight lines parallel to one another and to the lines which represent the results of experiments at the slower rates of 40, 62, and 84; but up to the present the series is not complete, and it may be that when the additional points have been obtained and charted the inclination of the lines may be slightly altered.

Speaking generally, the conclusions drawn from previous experiments are found applicable to the results obtained with these higher rates of movement. The 'cost of movement' *per se*, as distinguishable from the 'cost of work performance,' is represented by a definite distance along the abscissa, which distance increases with the rate, and then with each increment of work the 'cost' rises along a straight line starting from this point, so that the total cost may be summed as $H=\phi+xK$; for each particular rate of movement 'ϕ' being a constant, and 'x' a disefficiency coefficient which does not seem to vary in any obvious fashion throughout the whole series of experiments at all rates of movement.

It is intended to complete the series of experiments on this subject and to include the results in the report next year.

Vocational Tests.—*Report of Committee* (Dr. C. S. MYERS, *Chairman*; Dr. G. H. MILES, *Secretary*; Professor C. BURT, Mr. F. M. EARLE, Professor T. H. PEAR, Professor C. SPEARMAN, Mr. F. WATTS, Dr. LL. WYNN JONES).

The course of action outlined in the report presented by this Committee at the Southampton Meeting has been followed out. A list of institutions and bureaux throughout the world at which the psychological aspects of Vocational Tests are receiving attention has been compiled and is being added to as further information is obtained. A large number of names and addresses of those prominently engaged in this work have been collected. In order to obtain details of the work which has been done or is being carried out, a questionnaire has been sent to many of these institutions and persons. In some cases the replies have been prompt, but in others it has been necessary to write several times before the information required has been obtained, and all the answers have not yet been received.

Replies have been received from :—

1. State Board of Vocational Information, Wisconsin.
2. The Ohio Institute.
3. Bureau of Public Personnel Administration, Washington.
4. Colorado State Teachers College.
5. Teachers College, Columbia University.
6. University of Iowa.
7. University of State of New York.
8. Ohio State University.
9. Institut des Hautes Etudes, Brussels.
10. Office Intercommunal pour l'Orientation Professionnelle, Brussels.
11. Technical High School, Stuttgart.
12. Department of Guidance and Research, Public Schools, Atlanta, Ga.

Detailed references have been received from :—

1. Division of Vocational Counseling, St. Louis, U.S.A. Record cards.

2. Milwaukee Vocational School. Record cards used in job analysis. Specimen copy of series 'My Life Work' (Automobile Trades). Bibliography.

3. Institute of Educational Research, Teachers College, New York City. Record cards.

4. Bureau of Vocational Information, New York. Specimen copies of News Bulletin.

5. United States Employment Service. Record cards.

6. Vocational Guidance Bureau, Chicago. Record cards. Questionnaires. 'Futures.' A pamphlet on High School Opportunities. A series of Occupation Studies. A series of pamphlets on Conditions and Training for various occupations.

7. Personnel Research Federation, New York. Year Book. Annual Report.

8. Cabinet d'Orientation Professionnelle de Nantes. Record cards. Occupational Monographs. Form for Apprenticeship Contract. Advertisements and Propaganda forms. Report for year 1925. Booklet describing Vocational Guidance Service.

9. J. J. Rousseau Institute, Geneva. Reprint from Revue Suisse d'Utilité Publique. Report of 'Troisième Session ordinaire de l'Association Internationale pour la Protection de l'Enfant.'

10. Copenhagen University Psychological Laboratory. Booklet about Occupation. Two books published by School Association. Record forms used at Labour Bureau. Propaganda forms. One report.

11. Service d'Orientation Professionnelle, Strasburg. Record cards. Propaganda forms. Two reports.

12. Institut für angewandte Psychologie, Berlin. Specimen copy of 'Jugend und Beruf.' List of questions for job analysis. Bibliography.

13. Berufsberatungstelle, St. Gallen, Switzerland. Record cards and forms. Annual Report. Propaganda forms.

14. Bureau d'Orientation Professionnelle, Lausanne. Two Annual Reports. Pamphlet on Ability in Typewriting, published by International Labour Office.

15. Basel. Schweizerische Verband für Berufsberatung. 'Les classes de pre-apprentissage de Basel,' arranged by Schweiz. Verband für Berufsberatung und Lehrlingsfürsorge.

16. Bureau of Educational Research and Service, University of Iowa.

Specimen Tests have been received from :—

1. Division of Vocational Counseling, St. Louis, U.S.A. Intelligence tests. Tests of Mechanical Ability.

2. Technical High School, Stuttgart, Germany. Intelligence test. Selection tests for Salesmen, Technical Workers.

3. University of Copenhagen. Tests used at the Central Labour Office. Selection tests for Motor Drivers, Soldiers, Clerks, Compositors, Lithographers. Intelligence tests.

4. Psychotechnical Section of Neurological Laboratory, Basel. Cancellation test.

5. Cabinet d'Orientation Professionnelle, Nantes. Various test-sheets. Cancellation. Memory for form. Judgment of length. Arithmetic.

6. J. J. Rousseau Institute. Tests for Arithmetic, Aiming, Cancellation, Form Relation, Tracing, Group Intelligence. (Used also at Barcelona.)

7. Bureau of Educational Research and Service, University of Iowa. Iowa Placement Examinations.

It is hoped to exhibit these specimens, together with examples of tests prepared in this country by bodies such as the National Institute of Industrial Psychology, at the Conversazione to be held at the Oxford Meeting on Tuesday, August 10. More detailed information that is available can be obtained by those who desire this from the Secretary, and copies of specified tests may be obtained at cost price on application.

Of the British Association's grant of £14, £2 13*s.* 7*d.* has been expended. As the replies are not by any means complete, it is requested that the unexpended money be carried over and a further grant of £14 be given towards the completion of the work already in hand and towards expenses incurred in keeping the information up to date.

It is further proposed that the tests and results available be critically examined by the Committee during the coming year, with a view to the publication of those found to be of practical utility, if sufficient funds are available for the purpose.

Educational Training for Overseas Life.—*Report of Committee appointed to consider the Educational Training of Boys and Girls in Secondary Schools for Overseas Life* (Rev. Dr. H. B. GRAY, *Chairman*; Mr. C. E. BROWNE, *Secretary*; Major A. G. CHURCH, Mr. T. S. DYMOND, Dr. VARGAS EYRE, Mr. G. H. GARRAD, Sir RICHARD GREGORY, Mr. O. H. LATTER, Miss McLEAN, Miss RITA OLDHAM, Mr. G. W. OLIVE, Sir JOHN RUSSELL, Mr. A. A. SOMERVILLE, Mrs. GORDON WILSON).

In 1923-4 the Committee reviewed the provision made in secondary schools of England and Wales for developing a boy's natural bias towards life on the land, and for giving girls some practical training in those modern operations which are associated with farm life; they further dealt with the present state of public opinion on the subject from the point of view of the parent, the headmaster, the local educational authority, overseas settlement societies and educational authorities in the Dominions themselves.

In 1924-5 the Committee considered in more detail the work that is being attempted in certain schools of this country to arouse interest in farm life, and in agricultural studies generally. In their report issued last year at Southampton they were able to give, through the courtesy of headmasters, the syllabus of work adopted and the time-tables of the classes in these schools. The Committee further attempted to define the aim, content, and place of agricultural studies in the school curriculum. They emphasised the point that by 'agricultural studies' is not meant 'teaching to farm,' but that the farm or garden is to be used as a laboratory and workshop in the study of physics, chemistry, and biology. They put on record the expressed opinion of educationists in the Overseas Dominions that these agricultural studies should be regarded not as a vocational training, but as affording a practical outlook and purpose in the intellectual work of the schools.

The report further explored the many practical difficulties of finance, staffing, and examinations that stand in the way of a general adoption of such studies in schools where plenty of land is available.

In examining the position of urban schools it is suggested that, in the absence of available land for experimental purposes, geography has strong claims to be considered as a useful substitute, as affording a valuable means of opening the minds of boys and girls alike to the possibilities of a career abroad within the Empire.

The earlier inquiries of the Committee showed that there are a large number of schools eagerly awaiting the production of a practical scheme whereby the curriculum of the school can be broadened and rendered more adaptable to the demands of the Empire without sacrificing any of its educational breadth and efficiency. The chief obstacle to the production of such a scheme lies in the *laissez faire* of the people for whom such education might be offered. Many parents would welcome a development of school activities in the direction of more practical work in workshop, on the land, or in the laboratories, but their wishes are inarticulate, and so long as there is no general expressed desire for these practical studies, so long will the educational authorities ignore the need. Public indifference to such need not only holds up progress, but indirectly prevents experiments by those who would like to attempt them.

Examining bodies generally do not sufficiently grasp the handicap which practical work places on the candidates for the First School Certificate, as compared with the simpler order of studies provided for other pupils which only require book and paper.

The Committee therefore consider that, before an attempt is made to produce model courses and expend much time on detail, it would be better if the general principles underlying the movement for a more practical type of education were brought before the public, with the hope that a demand for it would be created. This, they believe, would be the first step towards its general adoption. They have therefore organised the meeting at Oxford on Thursday, August 5, for the purpose of drawing public attention to the urgent need for an extension of practical work in all secondary as well as the elementary schools, both in the interests of the Empire as well as for the sake of the boys and girls of the Homeland. The Committee wish through this meeting to emphasise the most important results of their investigation, viz., first, that a growing and widespread demand exists in the Overseas Dominions for boys

and girls well educated with an agricultural bias; secondly, that the country has an increasing need of finding healthy and profitable employment within the Empire for a large number of her sons and daughters; and thirdly, that practical studies of all kinds, especially those related to agriculture, possess a training value far too little realised by parents and by educational authorities. Though much of this practical work may have a vocational outlook, it is much more than that: it gives vision and reality to study, and creates a distinct interest, the underlying educational purpose of which is to make use of a natural environment for intellectual development, and for the growth of real appreciation of education.

Accompanying this report are two schemes of work still in the experimental stage, but embodying the ideas set forth in the reports already issued—one by Mr. W. G. Olive, headmaster of the Dauntsey School, Wiltshire, the other by Mr. H. W. Cousins, of the Brampton School, Cumberland; the second is printed below.

Brampton County Secondary School.

In the Report for 1924-25 the Science Syllabus of the above school is printed in some detail. The purpose of this paper is to indicate briefly where 'rural bias' is applied to other subjects of the curriculum and the extent to which so-called 'practical subjects' find a place in the time-table.

It is important to emphasise at the outset that the 'raison d'être' governing all the experiments at this school has been the wish to give children the best possible training—in every sense of the word—in a mixed school drawing its pupils from a district almost purely agricultural, and compelled on the one hand to prepare some pupils for the usual Lower and Higher School Certificates as a passport to the Universities and the professions, and on the other for life on the land or for entry to some trade or branch of business life. It has never been the purpose of the Governors or Staff to give definite agricultural teaching as a preparation for farming, to the exclusion of the interests of the majority of the pupils. Such a policy would have been fatal to the school and no less injurious to the best interests of the future farmer, and that for two main reasons—the district is not sufficiently populous to maintain a school with a purely 'farming' type of curriculum, while the segregation on vocational grounds of children of secondary-school age is most undesirable.

It is impossible in a short report to discuss the *pros and cons* of such a wide and deep subject as the curriculum of a school, or even to make a plain statement of the complete problem as it presents itself to one's mind. At the risk of being misunderstood, the writer must therefore content himself with a very brief statement of the essentials of a good curriculum as they appear to him.

1. It should have a real relation to the child's life—past, present, and future—otherwise it is almost impossible to secure the pupil's interest and co-operation, without which good work is impossible.

2. It should be broad enough to appeal to the many sides of the individual child and to the varied tastes and inclinations found in an average Form. To this end practical work—such as woodwork, metalwork, domestic subjects, dairying, &c.—and 'outdoor' work in geography, mathematics, science, history, &c., must receive proper recognition and an adequate allotment of time.

3. It should be sufficiently elastic in content and method to extend the 'keen and able' student without unduly depressing the *supposed* 'dull and backward.'

4. It must give reasonable opportunities for training children to appreciate art, music, &c.

5. It must, above all, secure that a child leaves school with the wish to learn by practice and through precept, and that he knows, when left to his own devices, how to learn.

Believing in these principles, the writer has continually urged members of his staff to base their teaching as far as possible on the lessons afforded and suggested by the school environment and to endeavour to give full play to the individual leanings of the children.

That does not mean the outlook is to be parochial, but that the local interest serves, not necessarily as a focus, but certainly to help to focus the world as a whole and to bring the individual into right relations with the community. The study, too, of the individual child, and the attempt to make the curriculum fit him instead of trying to fit him to the curriculum, gives every child the chance of proving that he is 'good' at something. This is most important. The traditional type of academic curriculum so often only serves to suggest to a boy that in comparison with his fellows he is a 'dunce.' Surely there is something wrong with a system that allows this! And is

it not true that the pupils who are thorns in the flesh of the Form Master often prove in after-life to be the very 'salt of the earth'? Among the men who have built our Empire—the pioneers, administrators, business men, &c.—men gifted with insight, initiative, organising capacity, &c., there are hundreds and thousands to whom the book and pen made little appeal.

If the school is to do its work thoroughly, it must recognise that the word 'ability' has a much wider meaning than is often granted to it, and must make provision for the 'practical' type of boy no less than for the fellow who is destined to shine in 'book' work.

The writer claims that for a country school a curriculum with a marked 'rural' and, in a limited sense, 'agricultural' bias, and which gives generous opportunities for so-called 'practical' work in many directions, provides a much better training for life for the average child than an education that is almost wholly bookish.

There are, of course, drawbacks to such practice. The requirements of the Lower School Certificate Examination present some difficulties, but examining bodies now look much more sympathetically than of yore on the claims of teachers to determine what they shall teach. After the Lower Certificate stage the difficulty in this direction vanishes. Indeed, it would appear from the evidence the writer has—an amount too small, however, for any sweeping generalisation—that far better work, both in quantity and quality, is obtained at this stage when pupils have worked for some years previously through a course with a marked 'rural bias.' This is, no doubt, largely because 'rural' work—in science especially—affords a unique training in patient and persistent observation and experiment over long periods of time, and discourages entirely the spasmodic and 'bitty' work that is not infrequently characteristic of pupils with high 'ability.' Again, as probably the majority of teachers will agree, success in academic work of Higher Certificate standard, or in the work of any business or profession, depends in the main on the individual's capacity and desire to map out and master his tasks without constant help from teacher or employer. It is comparatively easy to 'spoon-feed' the average pupil through the Lower Certificate stage, but almost impossible to carry him much farther by such means.

Now the intensity of interest that is secured when 'local' colouring is constantly given to lessons, when there are opportunities for clever 'practical' children to illustrate geography, history, and science lessons by models, apparatus, &c., made in the workshop, and when there is proper correlation between the various subjects of the curriculum, affords a training in initiative and self-reliance that is of the greatest value in the later years of the child's school career. In the early years of training method is everything. The content of the curriculum is then not nearly so important.

The whole matter, however, is too big to argue out in a short paper, but it is beyond question—in the writer's opinion—that pupils intending to take Higher Certificate and scholarship examinations are not at all handicapped in Science or Arts because they have worked on the lines indicated up to the Lower Certificate.

Experienced teachers will have little difficulty in appreciating the extent and directions in which mathematics, geography, and craftwork can be made more vivid and living by the application of 'rural bias.' The economic life of the countryside—the weekly transactions in the local 'market'; the periodical sales of cattle and sheep; the trade of cake, seed, wool, and corn merchants; the letting of 'accommodation' land; the effect of weather on prices, &c.—has a great attraction for the average country child. He often, too, displays an amazingly full knowledge of details which the wise teacher will not fail to make full use of as starting-points in many lessons.

History, again, is a subject made all the stronger in its appeal to the country child if taught with a strong 'rural bias.'

Thus, in dealing with the Tudor Period and tracing out the causes which, through the increased importance of sheep-rearing and a reduction in the amount of arable land, led to distress and unemployment among agricultural workers and to the Poor Laws of Elizabeth and of later years, one passes naturally and convincingly to a comparison with present-day conditions, when cheap grain from abroad increases the area under grass at home and displaces labour from the farms.

And, as with all the subjects mentioned specifically above, there is no subject of the curriculum that does not lend itself naturally and profitably to 'rural colouring.'

From the point of view of the pupil intended for life on the land, or for some occupation, such as accountancy, banking, business, that must bring him into daily contact with farmers and other landworkers, a curriculum on the lines favoured above must prove directly helpful both in increasing his love for, and sympathy with, rural

life, and in making him technically more efficient. Yet it is of the utmost importance to remember that much evidence is accumulating in this and other countries to prove that the same curriculum affords also the best possible training for any child living in the country, no matter where or what his future work may be.

It only remains to give some particulars of the 'practical' work attempted in connection with the science course.

Over two acres of land are under cultivation, and much of the actual manual work is done by a gardener and a general labourer whose wages are paid by the local education authority. The whole cost of labour does not fall on the authority, however, for the gardens supply all the potatoes and other vegetables used in preparing the school dinner—about eighty to ninety staff and pupils dine at school each day.

In the junior forms only the boys actually work in the garden, but both boys and girls make full use of the grounds and greenhouse as an open-air laboratory. In the senior forms boys and girls are on an equal footing, and make the fullest possible use of both garden and greenhouse, assisting in various cultural operations when necessary and carrying out regular and systematic work in plant physiology, control of pests, soil physics, &c., in pots and on the land. The time allotted to actual outdoor work at any stage of the course is not specified. Indeed, to do so would be altogether fatal to the meaning and value of the work. The object of the course is to train children in habits of scientific method and to make them useful citizens. It is not the aim of the school to teach the children to raise big crops of potatoes. If the course, however, does help them to grow bumper crops, so much the better.

In concluding this very brief account of a curriculum that has proved eminently practicable, it is hoped that fellow-teachers will be kindly in their criticisms.

The work is still in the experimental stage, and many factors exist which make both additions and eliminations difficult.

But even as it stands it is claimed that educationally it is sound, and that, up to the age of 16 or thereabouts, it meets the needs of every child, whether he be destined to enter a university or to follow the plough.

Distribution of Time.

The figures given below show the number of lesson periods per week allotted to each subject. Lesson periods are 40 to 45 minutes. Forms Va and Vb take the Lower Certificate.

	Va & Vb.		Vc.		IV.		IIIa.		IIIb.		II.	
	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.	B.	G.
Scripture	1	1	1	1	1	1	1	1	1	1	1	1
English	5	5	4	4	4	4	4	4	4	4	5	5
History	3	3	2	2	2	2	2	2	2	2	2	2
Geography	3	3	2	2	2	2	2	2	2	2	2	2
French	5	5	4	4	4	4	4	4	4	4	3	3
Mathematics	6	6	6	6	6	6	6	6	6	6	6	6
Science, including Outdoor Work	4	4	6	6	6	6	6	4	6	4	4	2
Manual Work	—	—	3	—	3	—	3	—	3	—	5	3
Domestic Science	—	—					—	3	—	3	—	2
			—	3	—	3						
Needlework	—	2					—	2	—	2	—	2
Drill and Folk Dancing	1	1	1	1	1	1	1	1	1	1	1	1
Preparation	3	1	2	2	2	2	2	2	2	2	2	2
Music	1	1	1	1	1	1	1	1	1	1	1	1
Games	1	1	1	1	1	1	1	1	1	1	1	1
Art	2	2	2	2	2	2	2	2	2	2	2	2
Total	35	35	35	35	35	35	35	35	35	35	35	35

Special pupils taking Latin may be allowed to omit Drawing or Manual Work or Domestic Science by arrangement with H.M.I., otherwise the subject is taken after the usual school hours.

Pupils in Form VI—*i.e.*, post-Matriculation—work to individual time-tables according to their requirements.

Domestic Science for Vc girls includes instruction in Butter-making and Soft Cheese-making. This work is linked up with the Science Course.

SECTIONAL TRANSACTIONS.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCES.

(For references to the publication elsewhere of communications entered in the following list of Transactions, see page 444.)

Thursday, August 5.

1. Prof. W. L. Bragg, F.R.S.—*Quantitative Methods in X-ray Crystal Analysis.*

In investigations of crystal structure it is assumed that waves in the X-ray region, scattered by the atoms of a crystal, obey the laws of interference which have proved capable of explaining diffraction in optical experiments. This assumption is justified by the success with which crystal structures of a simple type have been analysed. The strength or weakness of diffracted beams can be used in a very general and qualitative way to fix atomic positions with considerable accuracy.

Analysis may be made more precise by exact measurements of the ratio between the energy of radiation scattered by a crystal and the energy of incident beam. Evidence is accumulating that not only are the classical laws of interference obeyed, but that the amount of energy scattered by the electrons is given by the well-known electro-magnetic equations. This assumption has now been tested for a large number of crystals.

Crystal analysis assumes quite a new aspect when precautions are taken to obtain reliable measurements of intensity of diffraction. The distribution of scattering matter (electron density) throughout the crystal, and surrounding the atoms, can be deduced from the results, and structures of a complex type can be analysed. Though it is possible with rough estimates of intensity to analyse crystals with five or six parameters, and this has been done in several cases, such analyses are tedious and somewhat uncertain. When exact measurements of intensity are available, crystals with a number of parameters expressed in double figures present no great difficulty. We seem to be within measurable distance of achieving the ideal position when the structure of a crystalline body can be deduced as directly from the X-ray data, as can the form of a small object from its microphotograph.

In using the classical laws to explain X-ray diffraction we are confronted again by their incompatibility with the quantum laws for the interchange of energy between waves and matter. This does not necessarily invalidate the conclusions as to the distribution of electrons in the atoms drawn from the X-ray data, for in so many other cases the classical laws give the right solution, although there is such strong evidence that their fundamental interpretation requires to be modified.

2. Dr. J. E. Lennard-Jones.—*The Forces between Ions in Crystals.*

The first step towards the correlation of the physical properties of crystals lies in the determination of the forces between the constituent atoms and ions. The size and structure of the crystal cell, for instance, is conditioned by the forces of attraction and repulsion. In certain simple polar crystals of the rock-salt type the forces of attraction may be regarded as known (being electrostatic), and so the forces of repulsion alone require investigation.

In some recent researches it has been shown that the forces between certain ions in crystals can be correlated with the forces between the inert gas atoms. The latter have been found by the methods of the kinetic theory, and thus the properties of a crystal have been co-ordinated with those of a gas.

Theoretical calculations have been made of the interatomic distances of a large number of crystals which are in satisfactory agreement with the observed values. The

coefficient of compressibility and elasticity has also been calculated and found to be in fair agreement with the observed values (where these exist).

The information about ionic and atomic forces which has been obtained has been applied to other problems of crystal structure as yet unsolved. It has, for instance, thrown considerable light on the question as to why certain crystals such as CsCl set as body-centred cubics, while others such as NaCl set as face-centred cubics.

3. Sir William Bragg, K.B.E., F.R.S.—*Demonstration of Recent Crystal Models.*

4. Sir E. Rutherford, O.M., F.R.S., and Dr. J. Chadwick.—*Collision of α Particles with Light Atoms.*

5. Mr. W. W. Garrett.—*On Transformation of Elements by Low Voltage Discharges.*

6. Dr. F. J. M. Stratton.—*The Recent British Eclipse Expedition to Sumatra.*

7. Prof. H. H. Turner, F.R.S.—*Our Coming Total Eclipse.*]

Department of Mathematics.

8. (*a*) Mr. E. C. Francis.—*The Evolution of the Concept of an Integral from Riemann to Stieltjes.*

(*b*) Prof. C. Carathéodory.—*Some Applications of the Lebesgue Integral in Geometry.*

Though most people think that the Lebesgue theory of measure (and, what is practically the same, his theory of integration) has been only devised for the purpose of the theory of functions of a real variable, there are many instances where problems of geometry, ordinary analysis, or even mathematical physics, cannot be dealt with, if one discards the modern theories of sets of points and of measurement. The following three examples illustrate this fact:—

1. One of the simplest problems of geometry is to draw a tangent to a curve, and the simplest curves are those of finite length. The Lebesgue theory shows that those last curves have 'nearly everywhere' a tangent; that is, that if you take a point at random on the curve (or better, on an arc of the curve which you have rectified), there is the probability *one* that the curve will have a definite tangent at the given point.

2. The simplest analytical functions are those that are regular and bounded throughout the interior of the unit circle. If you take a point at random on the circle itself there is the probability *one* that the limit line $f(re^{\delta})$, as $z \to 1$, does exist.

3. The third example is the celebrated theorem of Poincaré that there is the probability *one* that in a steady motion of an incompressible liquid the path of a given molecule does return to any neighbourhood of the place where the molecule was located at the time $t=0$. At the time Poincaré gave this theorem (1890) it was impossible to understand the meaning of it, and Poincaré's proof was of course inaccurate. But twelve years later Borel and Lebesgue invented the new theory of measure by which the very proof of Poincaré was salved. It is now possible to give a much shorter proof of Poincaré's theorem of return that the original one.[1]

(*c*) Prof. G. H. Hardy, F.R.S.—*Trigonometrical Series.*

A survey of the subject.

[1] See C. Carathéodory, 'Über den Widerkehrsatz von Poincaré' (*Sitzber. Berl. Akad.* 1919, p. 580).

(*d*) Mr. E. C. TITCHMARSH.—*Fourier Transforms.*

(*e*) Prof. J. C. BURKILL.—*The Stieltjes Integral in Harmonic Analysis.*

Friday, August 6.

9. Joint Discussion with Section B on *The Mechanism of Homogeneous Chemical Reactions.* (See p. 343.)

10. Report of the Seismology Committee. (See p. 267.)
Prof. H. H. TURNER, F.R.S.; Dr. H. JEFFREYS, F.R.S.

11. Dr. J. HARTMANN.—*Demonstration of a new Air Jet Acoustic Generator.*

12. Prof. J. S. TOWNSEND, F.R.S.—*The Transference of Energy in Collisions between Electrons and Molecules.*

DEPARTMENT OF MATHEMATICS.

13. Dr. T. M. CHERRY.—*Orbital Dynamics.*

The removal of secular terms from the solution of Hamiltonian equations.

14. Dr. H. KNOX-SHAW.—*Hornsby's Meridian Observations at the Radcliffe Observatory.*

15. Prof. E. A. MILNE, F.R.S.—*Maxwell's Law and Radiation.*

Consider the atoms moving with a given volocity v in a gaseous assembly. It is shown that if their centre of mass undergoes a deceleration proportional to v, and if superposed on this each atom undergoes random increments of velocity, then the velocity distribution in the steady state is Maxwellian. This shows that the absorption and emission of quanta, according to Einstein's theory, leads to Maxwell's law. The theory is applicable to systems not in thermodynamic equilibrium, such as stellar atmospheres.

16a. Dr. A. A. ROBB, F.R.S.—*A Simple Form of Integraph.*

16b. SIR GEORGE GREENHILL, F.R.S.—*Division Values of the Theta and Zeta Functions.*

Graphical illustrations of the algebraic theory.

Afternoon visit to Radcliffe Observatory.

Monday, August 9.

17. Presidential Address by Prof. A. FOWLER, F.R.S., on *The Analysis of Line Spectra*; followed by contributions on Spectra from Prof. N. BOHR, Prof. P. EHRENFEST, Prof. C. RUNGE. (For Address, see p. 16.)

18. Prof. C. DAYTON-MILLER.—*Recent work on the Michelson-Morley experiment.*

DEPARTMENT OF MATHEMATICS.

19. Dr. A. M. OSTROWSKI.—*A General Theorem on Zeroes of Functions connected by a Linear Relation.*

20. Prof. W. R. VON DYCK.—*On Graphical Algebra.*

21. Prof. V. VOLTERRA.—*Mathematical Problems in Competitive Population.*

Tuesday, August 10.

22. Prof. M. BORN.—*The Quantum Mechanics of Electron Collisions.*

23a. Prof. W. WIEN.—*On the Direction of Electrons emitted by the Photoelectric and Compton Effect.*

It is well known that the number of photo-electrons expelled by polarised Röntgen rays has its highest value in the direction of the electric force of the incident wave. This result is in accordance with the electro-magnetic theory of light.

On the other hand, the emission of electrons by the Compton effect is a quite different phenomenon. Kirchner has made observations by stereoscopic photographs made of the tracks originated by Compton electrons in a Wilson case. By the stereoscopic observation it is possible to settle the direction in space of the electrons. Kirchner found that the number of electrons has its maximum at right angles to the electric vector. Though this result can be derived from the geometrical constellation, it seems paradoxical, because the classical theory shows no force at all in that direction.

23b. Prof. W. WIEN.—*On the Asymmetry and Intensity of Spectral Lines split in the Electric Field connected with the Direction of Impacts originating the Emission of Light.*

The Balmer lines of canal rays, split by the Stark effect, show a remarkable asymmetry of intensity, which is reversed with the field. In some recent new work Wierl has shown that, if the observation is made in a high vacuum, the asymmetry disappears. Therefore the asymmetry is effected by collisions of the moving atoms.

If canal rays of hydrogen are shot in a vessel filled with nitrogen, one has only moving atoms of hydrogen. Then one finds an asymmetrical intensity. If canal rays of nitrogen are going in hydrogen, the asymmetry is opposite, the impact on the hydrogen atoms having now the opposite direction.

This result shows that only the direction of the impact in relation to the direction of the field is responsible for the asymmetry of the lines. The asymmetry does not last any appreciable time, for it vanishes if the atoms pass after the collisions into a high vacuum.

24. Mr. R. d'E. ATKINSON.—*On the Mechanism of Light Emission from Atoms.*

25. Prof. L. VESSOT KING.—*The Gyro-magnetic Electron.*

A charged sphere in rotation was shown by Maxwell as long ago as 1870 to give a uniform internal field, and an external field equivalent to that of a magnetic doublet. The writer has considered the problem of determining the fields due to a spinning electron moving with uniform velocity v making any direction with the axis of spin, taking into account the deformation or contraction of the electron boundary into an ellipsoid of axes a and $a(1-v^2/c^2)^{\frac{1}{2}}$, the short axis being in the direction of motion. Regarding this as a real, physical deformation, the energy of the electrostatic and magnetic fields, internal and external, separates into two terms, one translational, the other due to components of spin $(\omega_1\omega_2\omega_3)$. The final result is

$$T=mc^2+\tfrac{1}{2}(A\omega_1^2+B\omega_2^2+C\omega_3^2)+\text{constant} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

In the first term, $m=m_0/(1-v^2/c^2)^{\frac{1}{2}}$, where $m_0=\frac{2}{3}e^2/a$ and account is taken of the boundary stresses (probably magnetic in origin) which keep the electron in equilibrium. The electrodynamic moments of inertia may be rigorously evaluated for the simple type of spinning electron considered, and in general may be expressed in powers of $\beta^2=v^2/c^2$ in the form

$$A=I(1+a_1\beta^2+a_2\beta^4+\ .\ .\ ), \qquad B=C=I(1+c_1\beta^2+c_2\beta^4+\ .\ .\ .\ ) \quad . \quad . \quad (2)$$

where $I=\frac{1}{3}m_0a^2$ is the moment of inertia of the spinning electron at rest. Applying Lagrange's equations to the rotations expressed by T as kinetic energy, the precessional motion of the electron is determined by Euler's equations,

$$A_1\omega=L_1 \qquad \left.\begin{array}{l} C\omega_2-(C-A)\omega_1\omega_3=L_2-Ck\omega_2 \\ C\omega_3+(C-A)\omega_1\omega_2=L_3-Ck\omega_3 \end{array}\right\} \quad . \quad . \quad . \quad . \quad (3)$$

$(L_1L_2L_3)$ being couples from nuclei in atomic systems, or due to the magnetic forces of the radiation field. The precessing electron has magnetic moments proportional to $(\omega_1\omega_2\omega_3)$ whose periodic variations thus give rise to electro-magnetic radiation of the same frequency. The constant k is a simple type of damping factor due to the loss of rotational energy by radiation. Under no forces the stable configuration of the electron is easily seen from (3) to be with the axis of spin along the direction of motion. When disturbed the frequency of precessional motion and of emitted radiation is seen to be, if Ω_1 is the intrinsic spin,

$$2\pi\nu=\Omega_1(C-A)/C=\Omega_1(c_1-a_1)\beta^2(1+b_1\beta^2+b_2\beta^4+\ .\ .\ .\ ) \quad . \quad . \quad . \quad (4)$$

If we denote

$$h\Omega_1=\pi c^2m_0/(c_1-a_1), \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

where (c_1-a_1) is a numerical constant equal to $\frac{4}{5}$ for the simple model considered, we have to a first approximation a relation between *precessional electron radiation* and *velocity* in the form

$$h\nu=\tfrac{1}{2}m_0v^2, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

the well-known photo-electric equation, while *Planck's constant h becomes a fundamental characteristic of a rotating electron expressed in terms of spin by equation* (5).

This purely classical interpretation appears to be the key to radiation problems generally. With similar hypotheses as to spinning protons as constituents of atomic nuclei, the theory of slightly perturbed, simple orbits under an inverse-square law of electrostatic attraction from the nucleus, with the fundamental relations (6), leads to the series formula for hydrogen and helium spectra and in more complex cases to the S, P, D and F series, with the correct value for the Rydberg constant. Perturbations of orbits due to variation of mass with velocity, external electric and magnetic fields, with in some cases slightly different interpretations, lead to formulæ the correct type for fine structure, Zeeman (normal and anomalous) and Stark effects. The fundamental formula (6), used in conjunction with a Maxwellian distribution of electron velocities, also leads with reasonable hypotheses as to electron orbits in a space lattice to Planck's formula for black-body radiation and the associated formulæ for specific heats.

26. DR. S. G. BARKER, MR. A. T. KING, and MR. H. R. HIRST.—*The Hygroscopic Relations of Colloidal Fibres, with Special Reference to their Industrial Importance.*

The theory of elasticity of colloidal fibres is developed, and it is shown that wool fibres follow the usual characteristics of colloids. There is apparently an elastic framework filled with a viscous medium. The effect of moisture absorption on the viscous phase is discussed, and it is found that wool is a perfectly elastic material and makes a complete recovery from strain even up to its breaking point. The effect of moisture on thermal and electrical conductivity is discussed. In the former case it is shown that the increase in thermal conductivity of any material for an increase of moisture content of 1 per cent. of the dry weight ranges from 1.7 to 2.0×10^{-6} for wool.

The electrical conductivity is shown to increase with moisture content, and it is noted that dry fibres are non-conducting. A table of results is given. Section II treats of the variation of density, swelling, and heat of wetting of wool, and from the results a theory of wool structure is put forward. Tables are given for density measurements and heat evolved upon wetting at various humidities.

Section III deals with technical applications of the problem, and mentions, *inter alia*, setting of wool, finishing processes, and the effect of humidity on the fading of dyestuffs on woollen fibres. The influence of moisture content on the production of bacteria is discussed.

27. Reports of Committees.

Department of Mathematics.

28. Mr. F. P. Ramsey.—*Mathematical Logic.*

The paper explains certain problems of fundamental importance to mathematics which were left unsolved in *Principia Mathematica*, and gives a critical account of theories by which Weyl, Brouwer, Hilbert, Wittgenstein, and the author have tried severally to meet the outstanding difficulties.

29. Mr. M. H. A. Newman.—*Combinatory Topology.*

The establishment of the analysis situs of n-dimensional spaces on principles independent of the theory of infinite aggregates.

30. Mr. T. W. Chaundy.—*Commutative Operators.*

A sketch showing how the study of commutative pairs of ordinary differential operators is begun and pointing out the relation of the subject to a number of classical problems in analysis and geometry.

SECTION B.—CHEMISTRY.

(For references to the publication elsewhere of communications entered in the following list of Transactions, see page 445.)

Thursday, August 5.

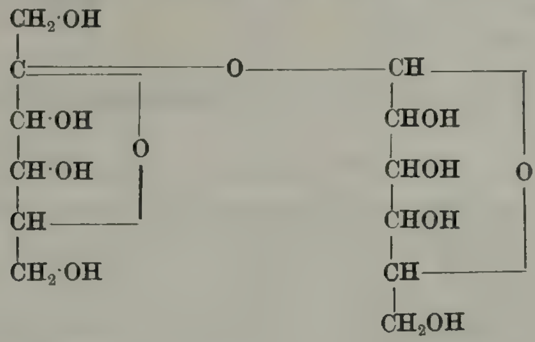
1. Presidential Address by Prof. J. F. Thorpe, F.R.S., on *The Scope of Organic Chemistry.* (See p. 46.)

2. Prof. J. Backer.—*Separation and Racemisation of Simple Optically Active Compounds.*

3. Prof. W. N. Haworth.—*Modern Views on the Structure of the Disaccharides.*

A marked advance made in the constitutional study of sugars is the generalisation that the aldoses normally occur as amylene-oxide forms ; that is, having a heterocyclic six-membered ring and not as was formerly thought a five-membered ring (butylene-oxide), and further that the γ-aldoses are butylene-oxide sugars. (A revision of the structural formula of glucose : Charlton, Haworth and Peat, *J. Chem. Soc.*, 1926, 89 ; *cf.* Hirst, *ibid.*, 352.) Difficulty was experienced in including the ketoses in this classification owing to oxidation results obtained with fructose derivatives, which pointed to the converse rule. Recent experiments (Hirst and Haworth) indicate, however, that the structure given to normal fructose by Irvine is invalid, as is also that applied to γ-fructose derivatives by Haworth. Both normal and γ-fructose are now included in the generalisation already applied to the aldoses. This fundamental advance involves a large readjustment of our ideas as to the formulæ of disaccharides and polysaccharides. The possibility of the occurrence of γ- or butylene-oxide residues in the disaccharides was first suggested in the above paper by Charlton, Haworth and Peat. The structural formulæ applied to lactose,

cellobiose, and maltose admit of this formulation, as also sucrose, raffinose, and inulin. The most satisfactory formula which can be allocated on these principles to sucrose is the following :—



Fructose residue

Glucose residue

3a. Mr. A. Chaston Chapman, F.R.S., and Dr. H. J. Plenderleith.—*An examination of King Tut-ankh-Amen's Cosmetic.*

Friday, August 6.

4. Joint Discussion with Section A on *The Mechanism of Homogeneous Chemical Reactions.*

(Mr. C. N. Hinshelwood outlined the objects of the discussion, which was opened by Prof. Jean Perrin.)

Monday, August 9.

5. Discussion on *Tautomerism*: Prof. C. K. Ingold, F.R.S.; Prof. T. M. Lowry, F.R.S.; Dr. G. R. Kon; Dr. R. P. Linstead; Prof. J. F. Thorpe, F.R.S.

The scope of tautomerism (reversible isomeric change) is prescribed by reference to the fundamental types of addition reaction of which tautomeric change represents the intramolecular case, the basic condition being the simultaneous presence of mutually suitable dissociable and unsaturated centres. From this standpoint some long known, and some recently investigated, types of tautomeric change are discussed, with reference to the effect of structural conditions on mobility and equilibrium. Comparisons are drawn between the directive effect of groups in aromatic substitution and their ability to 'direct' the mobile hydrogen atom into the favoured position.

The above points are illustrated by reference to such classes of compounds as *cyclo* Pentadienes, Benzene derivatives, Glutaconic esters, Nitro-compounds, Sugars, Oximes, and Diazo-compounds, and explanations based on the assumption of tautomeric change are given for certain peculiarities of these substances.

Tuesday, August 10.

6. Prof. H. ter Meulen.—*The use of Hydrogenation in Organic Analysis.*

The usual methods for the estimation of sulphur, halogens, nitrogen, arsenic and mercury in organic compounds are based upon destructive oxidations. These determinations can be made quicker by using destructive hydrogenation, which enables us also to estimate oxygen. As a rule the substance that is to be analysed is heated in a quartz tube through which a current of hydrogen is passed; in most cases katalysators are used to promote hydrogenation.

Sulphur is converted into hydrogen sulphide, which is estimated by titration with iodine solutions; if the amount of sulphur is very low (*e.g.*, in coal-gas and oil),

a colorimetric method may be used. Halogens yield halogen acids, which are titrated by the method of Volhard. The nitrogen of organic compounds gives ammonia, which is also estimated volumetrically. Oxygen is changed into water that is weighed after absorption in calcium-chloride. Arsenic and mercury are both set free and weighed in metallic state.

7. Mr. J. J. Manley.—*The Union of Mercury and Helium.*

8. Dr. G. Martin.—*The Chemistry of Fine Grinding and Fine Powders.*

The subject of fine grinding and fine powders has attracted an increasing amount of research work during the last few years. Fine powders behave in many respects like fluids, and possess many curious properties, especially when colloidal dimensions are approached. The mathematical laws regulating their production have only been ascertained between 1923 and 1925 by researches carried out by the author and his assistants. The powders were produced in an 18-in. by 18-in. experimental tube-mill, using quartz sand and 1-in. steel balls. The powders were subsequently elutriated in a stream of air of definite and measured speeds, and the weight, number, and surface of the particles composing them were ascertained.

The following laws were found to hold rigorously :—

Law 1. *The surface produced is accurately proportional to the work done. Double the work and the surface produced is doubled, treble the work and the surface produced is trebled.*

The cause of this is the constant nature of molecular attraction. In a liquid the work done in extending a film is also proportional to the surface, because here also the surface tension is a constant force.

Mathematically expressed,

$$W = B\,(S_2 - S_1),$$

where W is the work done, S_1 the original surface of the powder, and S_2 the final surface. B is a constant peculiar to the material ground and also depending upon the efficiency of the mill.

The heat of volatilisation of a substance is obviously equal to the work done in grinding down to molecular dimensions. Substances difficult to volatilise (*i.e.* with a high heat of volatilisation) in general are difficult to grind (compare ice and the diamond). From such considerations and recent determinations of molecular dimensions the absolute efficiency of a tube-mill may be calculated as being only about 1/15th per cent. ; so that great improvements in grinding machinery are theoretically possible.

Law 2. *The number N of particles produced increases with decreasing diameter X according to the compound-interest law.*

In symbols, $N = ae^{\cdot bx}$,

where N is the number of particles, x is the diameter, a and b are constants, and e is the Napierian base of logarithms.

Consequently, plotting the logarithm of the number against the diameter gives a straight line.

Also the weight W of any grade of particles can be ascertained, because plotting Log W/X^3 against X (where W is the weight of the grade and X the average diameter of particles forming the grade) likewise gives a straight line.

Law 3. *The average shape of the particles produced in crushing remains the same whether they are large or small.*

If S be the statistical surface of the particles of any diameter X, which compose a homogeneous grade, then

$$S/X_2 = \text{constant A, or } S = AX^2$$

For quartz sand experiment showed that A equals 2 nearly.

Law 4. *Crushed sand coming from a grinding mill is composed of homogeneous grades of crushed sand, in which the distribution of the numbers of the particles with their diameters cannot be altered, no matter how often we regrade the sand.*

These statistically homogeneous grades of sand may be considered as the unalterable elements which compose a given mixture of sand particles. In such a homogeneous grade the distribution of the particles follows the probability law.

This was proved by separating out the sand coming from a tube-mill (and whose particles follow the compound-interest law, $N=ae^{\cdot bx}$) into separate grades by repeated air elutriation.

One of these grades was then air-elutriated some eight or nine times without in any way altering the distribution of the particles therein, which was found to follow the probability law, $N=ae^{\cdot bx^2}$, where N is the number of particles of a given diameter x; a and b are constants.

9. Dr. E. S. Semmens.—*Hydrolysis by Light Polarised by Colloidal Particles: Contribution to the Study of Enzyme Action.*

The undoubted selective effect of polarized light in biochemical reactions, which has been abundantly confirmed during the past three years, together with the fact that enzymes, being colloidal, exhibit the Tyndall polarizing effect very strongly, suggests that the polarization of incident radiation is an important factor in enzyme action.

To demonstrate this, the following experiments were made :—

A small, flat-bottomed, thin-walled flask, containing a suspension of well-washed potato-starch grains in distilled water, was irradiated on its base by light, polarized by colloidal particles of a strong taka-diastase solution contained in an outer beaker. In the control, the flask was waxed and the outer beaker held plain tap-water.

At intervals of two or three days, a few drops from each flask were examined on a microscope slide and the results were briefly as follows :—

(*a*) After bright illumination, the grains in the first flask were found to be breaking down rapidly, those in the control being practically intact.

(*b*) After feebler light, the grains were seen to be hollow, hydrolysis commencing from within and extending by canals to the exterior.

On heating with Fehling solution, reduction was observed and particles of cuprous oxide were seen revolving inside the grains.

(*c*) With longer exposure, on slowly drying, crystals were seen forming within the grain or exuding from it. The liquid became viscous and, after several weeks, bundles of needle-shaped crystals slowly formed in the liquor.

(*d*) Under certain conditions, a fatty film was seen, together with hexagonal or rhomboidal crystalline plates, produced apparently from the broken-down shells of the grains.

As in all these cases the enzyme was *outside* the vessel containing the substrate, these visible signs of hydrolysis point strongly to the conclusion that the orientation of the light (or heat) vibration is at least one of the factors of enzyme activity.

SECTION C.—GEOLOGY.

(For references to the publication elsewhere of communications entered in the following list of Transactions, see page 445.)

Thursday, August 5.

1. Presidential Address by Prof. S. H. Reynolds on *Progress in the Study of the Lower Carboniferous (Avonian) Rocks of England and Wales.* (See p. 65.)

2. Prof. W. J. Sollas, F.R.S.—*The Geology of the Oxford District.*

3. Prof. Sir T. W. Edgeworth David, K.B.E., F.R.S.—*The Determination of the Age of the so-called Permo-carboniferous Tillites of Australia.*

Recent research in Australia, notably by C. A. Süssmilch, has shown that the oldest and chief horizon of the so-called Permo-carboniferous glacial deposits of Australia is associated, in N.S. Wales, with a fossil flora of Culm type, dominated by *Rhacopteris, Cardiopteris* and *Archæocalamites*. Observations last year by Dr. A. L. du Toit, in South America, prove that *Cardiopteris* is there associated intimately with the main glacial horizon at the base of what is thereby shown to be an Upper Carboniferous series. In India the Lower Productus Limestones, marking the base of the Permian System, are considered to be stratigraphically above the marine beds with *Eurydesma cordatum*, which immediately overlie and are partly interstratified with the Talchir boulder beds.

In South Africa the Dwyka Tillites pass westwards, to the south of Windhoek, under the *Eurydesma globosum* beds, and eastwards are followed by the Dwyka Shales, which contain crustacea of Upper Carboniferous affinities, the flora also indicating a similar age. The present researches of H. D. Thomas of Cambridge on the so-called *Gastrioceras jacksoni*, from the Irwin River coalfield of Western Australia, show that that cephalopod, so abundant above the main glacial horizon there—the 'Lyons Conglomerate'—belongs probably to about the middle of Upper Carboniferous time.

Thus, so far, throughout the Southern hemisphere evidence points to the chief glaciation in late Palæozoic time having taken place not in Permian but in Upper Carboniferous time. It is possible that evidences in New South Wales of a smaller and later glaciation should be referred to very late Carboniferous or Early Permian time.

4. Prof. E. S. Moore.—*The Keweenawan Series at the Eastern End of Lake Superior.*

The Keweenawan system, at the eastern end of Lake Superior, consists of three series. The lower one is entirely igneous, the middle one igneous and sedimentary in origin, and the upper one sedimentary. The genesis of these series is closely related to the early history of the Lake Superior basin, which has been in existence since Pre-Cambrian time. The development of dikes in this region, during the Lower Keweenawan epoch, is believed to be the most remarkable ever discovered in the Canadian 'shield.' The Middle Keweenawan is a series of interbedded lavas and conglomerates, exceeding 16,000 feet in thickness, and the conglomerates contain boulders of granite up to 4 feet in diameter. These have suggested a glacial origin to most of the geologists who have seen them, but in the opinion of the author they are not glacial.

A study of this section has shown that the quartz-diabase and olivine-diabase dikes, so common in the Pre-Cambrian areas of Northern Ontario, probably belong to the Lower Keweenawan and Middle Keweenawan respectively.

The great epochs of igneous activity appear to have been one expression of the disturbances accompanying the deepening of the Lake Superior basin.*

5. Dr. R. T. Gunther.—(1) *Notes on Exhibits of Blood Stains on Kimmeridgian Vertebra and of Jaw of Ursus Anglicus found in Magdalen College.* (2) *The Oldest Stratigraphical Collection in the World—the Collection of John Poynter*, c. 1720.

Afternoon.

Excursion to Hanborough, Stonesfield, &c.

Friday, August 6.

6. Discussion on *Problems of the Thames Gravels.* Opened by Mr. S. Hazzledine Warren and Dr. K. S. Sandford.

* Published by permission of the Ontario Department of Mines.

(*a*) Mr. Warren.—*The Lower Thames.*

The paper discusses the broader principles of the formation of the river terraces, and of the relative parts played by the process of erosion and the process of deposition.

As the Pleistocene river deposits are markedly unlike the river deposits of the present day, or of the Neolithic and Bronze Ages, it is inferred that the Pleistocene rivers were equally unlike the present rivers. Although that is familiarly known, its consequences have not always been sufficiently kept in view in theoretical problems.

It is important to obtain some estimate of the depth of water that was present in the Pleistocene rivers, and never to overlook the contemporary formation of deposits upon the flood-plain and in the river-bed. Although of different level, such deposits must, under the conditions specified, be of one epoch. The succession of the Palæolithic industries is questioned by many geologists, but it is suggested that if the industries be taken in conjunction with this modified view of the terraces, the two become mutually illuminating.

In the Maidenhead district, Mr. Treacher has identified gravels which are intermediate between the Boyne Hill and Taplow terraces. These are named the Furze Platt gravels, and it is these exclusively that yield the Palæolithic industry of which the Gray's Inn Lane implement found in A.D. 1690 is a typical example. The original Boyne Hill gravels appear to yield only the industry which was called the 'oldest class' by Worthington Smith.

The author concludes that the gravels yielding the Gray's Inn Lane industry throughout the Thames Valley, even although not upon one level, should be separated from both the Boyne Hill and the Taplow terraces, and placed in the Furze Platt stage.

(*b*) Dr. K. S. Sandford.—*Features of the River Gravels of the Upper Thames Basin.*

The highest river-terrace (80-100 ft. above present river-level) is younger than the various deposits grouped as Plateau Drift, which contain large quantities of erratic material not infrequently bearing glacial striæ. The erratic material thus reappears in the river-terraces. There can be no doubt that there was a glaciation—the maximum development in the Southern Midlands—before the High Terrace was formed. The High Terrace contains a 'warm fauna' (as at Handborough), including a variety of Elephants, and is probably to be correlated with the High Terrace of the Lower Thames.

The rivers deepened their beds some 50 feet, and in a terrace, now fragmentary, rolled Chellean implements have been found; the deepening process was continued almost to present river-level, and a widespread terrace at about 15 feet deposited. This contains a 'cold fauna' at the base—abundant mammoth, with woolly rhinoceros and bison, but no reindeer—covered unconformably by gravels with a well-marked 'warm fauna' (*Elephas antiquus, Hippopotamus, Corbicula fluminalis*, etc.).

Rare Upper Acheulean implements have been found in this double terrace. A period of aggradation seems to have followed, for the deposits are next found in a channel cut through the older terrace (about 40-50 feet) at Wolvercote. The 'warm fauna' remains, with unworn implements of Upper Acheulean and Micoque industries; sands with temperate shells follow, then a peat (now destroyed) of temperate or cold temperate character. Lastly follow thick clays, completing the filling of the channel, in which flakes have rarely been found (probably Mousterian), and one antler of reindeer. The clays are covered and disturbed by 'frozen-soil gravels'—a complete change of climate being marked as we pass from bottom to top of the channel. Lastly the rivers deepened their channels: the surface of the 15-feet terrace was disturbed in the process and capped by slight thicknesses of gravel. A channel was cut some 30 feet below the present rivers and was subsequently filled with sand and gravel in which the mammoth seems to occur again. This downward movement is most probably contemporary with the frozen-soil gravels and of Upper Palæolithic age.

Professor Marr was interested in the 'cold' fauna below the Hippopotamus-bearing beds. He thought it possible that the apparent absence of the former in the district was due to actual occupation of that area by ice.

Mr. Llewellyn Treacher congratulated Mr. Warren on introducing the term Gray's Inn Lane Type to describe a set of implements which is also characteristic of the Furze Platt gravels in the Middle Thames Valley from Reading to Maidenhead

and further east. These gravels constitute an impersistent terrace between the levels of Boyne Hill and Taplow terraces, and they are the only deposits in this district which contain fresh and unrolled implements. They may therefore be taken as a useful datum line. The higher or Boyne Hill gravels contain only much-rolled specimens rather small in size and either sharp-rimmed ovate or bluntly pointed in form. Moreover, they are very scarce and their original home has not yet been discovered. Probably they were swept off an old land surface which has long since disappeared. The implements in the Taplow gravels are always rolled, and obviously derived from the Furze Platt deposits, being only found in those localities where the latter are well developed. The above views are based on nearly forty years' close observation of most of the excavations made in the district.

Rev. Charles Overy.—The occurrence of Leytonian implements in the Taplow Terrace near Maidenhead as derivatives is probably to be explained by the destruction of the 135-ft. to 140-ft. terrace so well marked north of Reading, from which the speaker has obtained many implements.

The succession of plateau gravels at definite stages ranging from 350 feet above river-level to the Handborough Terrace with glacial erratics is very distinctly marked in the Oxford area, and includes a well-marked series at 200 feet above river-level corresponding with Mr. Wooldridge's base level in the Lower Thames.

7. Mr. S. S. Buckman.—*Shotover Brickyard : the Age of the Clay above the Shotover Grit.*

8. Papers on *Geological Technique and Research Methods* (Mr. I. S. Double, Prof. W. T. Gordon, Prof. H. L. Hawkins, Dr. A. Heard, Dr. E. Neaverson, Dr. H. Hamshaw Thomas, Mr. John Walton, Dr. W. F. Whittard).

Prof. W. T. Gordon.—*The Preparation of Thin Rock-sections.*

The origin of the idea of examining the internal structure of stony material by means of thin sections is quite uncertain, and was probably a development from the methods of early crystallographers, who prepared thin slices of minerals for optical examination. For instance, we find Brewster, in 1817, making slices of amethyst one-fiftieth of an inch thick for optical research. It is interesting to note that lapidaries were employed in preparing such sections, and, as these operatives had long been accustomed to prepare slices of agate and other materials for decorative purposes, we cannot be surprised that much credit is deservedly given to them. When the importance of the process was fully realised, it seems to have become impossible to give the credit to anyone in particular, but the history of the method, so far as it is known, is not without interest. The earliest publication describing the process of manufacture was by Witham in 1831.[1] He attributed his knowledge of the method to Nicol, and certainly described Nicol's modification of Sanderson's method.[2] An enlarged work in 1833 does not contain this description, and on that account, as well as for other reasons, Nicol seems to have become incensed at the work and also the author.

Nicol gave vent to his passion in a paper published in the 'Edinburgh New Philosophical Journal,'[3] and, though petulant in tone, the article is of some importance in clearing up the vexed question about the origin of section-cutting. Nicol makes no claim to have originated the idea, but states that the first 'in this quarter' (Edinburgh) to make thin sections of fossil plants was a lapidary, Sanderson by name—the man also mentioned by Witham. Sanderson's method was to slice a piece from the specimen and fix it down, by means of lapidary's cement, to a wood block, thereafter smoothing *and polishing* the exposed surface. The cement was softened, the slice reversed, and the under surface now rubbed down until it was considered sufficiently thin for the purpose on hand. This surface also was polished, and, on re-melting the

[1] 'Observations on Fossil Vegetables.' Edin. 1831.

[2] 'The Internal Structure of Fossil Vegetables.' Edin. 1833.

[3] 'Observations on the Structure of Recent and Fossil Coniferæ.' *Edin. New Phil. Journal.* 1834.

cement, the thin section, polished on both surfaces, could be mounted on a suitable piece of glass and examined under the microscope.

Nicol's claim to consideration is that he substituted a glass plate for the wood block, and canada balsam for the lapidary's cement. Thus, he says, the specimen could be reduced to any desired thickness and could be examined at any stage. Now this is an important improvement of the older method, and Nicol states, in 1834, that he had been using it for fifteen years.

Yet he did not appreciate to the full the importance of the process, and in the same article gives to Prof. Lindley the credit of having drawn attention to its possibilities.[4] Yet Lindley in 1831[5] had already given that credit to Witham. The situation is further obscured by an editor's remark (at the end of Nicol's paper) that he—Prof. Jameson—had long known the method *and had advocated its use to geologists.*[6] The latter phrase indicates that Jameson had foreseen what Sorby put into practice forty years afterwards. Truly both Brewster and Nicol had made thin sections of *discrete minerals*, but Sorby was inspired to apply the method to *rocks* after a visit to Edinburgh, where he examined the collection of slides and specimens belonging to Alexander Bryson. This collection contained Nicol's sections, as well as many prepared by Bryson himself, and its treasures were available for all those interested in the study. It is sometimes stated that Williamson of Manchester showed Sorby the method; but such is not the case, though he may have helped Sorby in the preparation of the sections.

Modern practice differs little from Nicol's improved process. It is true that *polishing* is no longer required, for the refractive index of canada balsam is sufficiently close to that of most rock-forming minerals to obviate the necessity of securing transparency by polishing the surfaces. The use of glass coverslip protects the surface from damage and renders the upper surface transparent, while the transference to a clean slip of glass gives a more workmanlike finish than was formerly obtained. Improved and new abrasives have 'speeded up' the manufacture, and an average section may easily be made in from twenty to thirty minutes. Dry grinding and wet grinding are both used, the former in special cases where the material might break down if wetted, while gum arabic, shellac, and other media are employed under certain circumstances. Specimens illustrating various stages in the process were shown, while some hints on 'cooking' the canada balsam and transference of the finished sections were given.

Prof. H. L. Hawkins.—*Preparation of Fossil Echinoderms.*

The only special difficulties in this group are due to the crystalline cleavage of the calcite, whether primary or secondary, of the stereom. Since this cleavage is always at an angle to the surface of the test or ossicle, mechanical separation of the specimen from its matrix has to be carried out with absence of jarring and the minimum of pressure. Except in the case of chalk specimens, the test is normally softer (as well as more friable) than the matrix, so that slow progress and delicate manipulation are required.

Calcite specimens that have been freed from an argillaceous matrix by caustic potash need saturation with wax afterwards to prevent crumbling of the stereom.

Sutures may be revealed (but not with certainty of success) by exposure of the test to the action of the humic acids generated in rotting vegetation.

Dr. A. Heard.—*On a New Method of Treating Pyritised Plant Remains.*

By this method, pyritised fossil plants of Devonian age, which originally exhibited no trace of their internal morphology, have yielded every detail of the internal anatomy of the vegetative organs.

Fragments of the plants are embedded in a suitable mounting medium, *e.g.* shellac, and sectioned in the desired direction. The section is very carefully polished and treated with concentrated nitric acid, with, in some cases, potassium chlorate added. The cell structures develop rapidly, and are observed in incident light.

[4] Nicol, *loc. cit.*, p. 156.

[5] Lindley and Hutton. *Fossil Flora*, vol. i, p. xxviii. 1831.

[6] Nicol, *loc. cit.* Editor's remark at end of article.

With favourable specimens the pyrites may be completely removed. In order to obtain successful results the greatest care must be exercised in the final polishing of the section.

Dr. E. Neaverson.

Methods of preparing fossil brachiopods to show internal features depend upon the preservation of the fossil, the nature of its matrix, and on the features which it is desired to exhibit—whether brachial supports projecting freely into the shell cavity, or muscle-scars and ovarian markings impressed upon the internal surface of the shell. Various methods of preparation will be discussed and illustrated.

Dr. H. Hamshaw Thomas.—*The Investigation of the Structure of Mummified Fossil Plants.*

The old method of maceration which reveals the structure of cutinised cells can be used for some bulky remains, such as buds or fruits, and the membranes and remains of spores, which can often be extracted from them, show that some of the internal structure is preserved. A method has been devised for investigating the structure of the fruits of Caytonia, which at first seemed composed of homogeneous material.

The fruits are removed from the rock, cleaned, softened, embedded in celloidin and cut into thin sections with a microtome. The sections, which show little or no structure, are now treated with reagents, which effect a partial solution of the material, and in so doing render the structure visible. Good results were obtained with $KClO_3$ in strong HCl, followed by a very dilute alkaline solution. The sections were subsequently stained and mounted. By this treatment, cutinised, stony, or fibrous tissues become visible. Other solvents reveal the position of the middle lamella of the cell walls. The method is probably capable of extension to some other plant remains, but possesses certain difficulties.

Mr. John Walton.—*The Transfer Method of Examining Fossil Plant 'Impressions.'*[1]

The surface of an ordinary hand-specimen of an 'impression,' or what is more correctly termed 'incrustation,' of a fossil plant is usually a damaged surface; this is a necessary consequence of the fact that in order to expose such a fossil to view the rock must be split open. The two surfaces of a plant-fragment are usually of a different nature, and the split tends to pass over and expose to view the more even of the two surfaces. The other surface is not shown; it is probably the most interesting, and, as it may bear sporangia, hairs, or other emergences, it is an advantage to be able to expose it to view in an undamaged condition.

This may be done by cementing the specimen face down to a glass slide with fused canada balsam, protecting the uncovered glass surface with wax. By removing the rock with hydrofluoric or some other suitable acid, the plant residue is left sticking to the balsam, and the surface of the plant originally hidden next the rock is now exposed to view.

As the support and cement are transparent, the fossil may now be examined by transmitted light, and many such fossils will reveal a certain amount of structure when seen in this way. When the fossil to be examined consists of very fragile films or particles of organic material, the method of transfer enables one to examine them by transmitted light without any alteration in their space relationship to one another. In many instances a fossil of a leaf may be represented by numerous particles; the fossil, if removed from the rock by direct maceration, is resolved into its particles, which separately may exhibit no structure, but if kept together in a transfer often reveal otherwise unobservable features.

A great improvement on this method, more particularly in its application to the examination of small organic particles and thin organic films, has been devised by Mr. E. Ashby (to be described shortly by Prof. W. H. Lang in the *Annals of Botany*). This consists in using a cellulose film instead of balsam as a support for the fossil residues. The main advantage gained by this device is the possibility of making preparations of a more permanent nature and in avoiding the use of glass slides and paraffin-wax. It is not, however, of such general application as the balsam method,

[1] Described in the *Annals of Botany*, vol. xxxvii., July 1923.

as large, solid incrustations are liable to crack up when merely supported on a flexible film.

I have found that a modification, combining the essential processes of both methods, is of great assistance when one cannot tell whether the preparation is to be kept uncovered or not. This enables one to convert a preparation of the uncovered type into one of the covered, more permanent, type without much difficulty. The advantage of keeping a preparation uncovered is that features of relief are almost entirely lost when the surface is covered with balsam.

Dr. W. F. Whittard.—*Method of Study of the Detailed Structure of Graptolites Preserved in Calcareous Grits.*

In Harper's Dingle on the south-east flank of the Wrekin (Shropshire), there outcrops a thin band of calcareous grit of Upper Valentian age. In addition to a shelly fauna, characterised by an abundance of *Pentamerus oblongus*, J. de C. Sow, the grit has yielded numerous specimens of *Glyptograptus tamariscus* (Nich.) associated with rare *Monograptus nudus*, Lapw., and *M. gemmatus*, Barr. The rock consists of angular quartz grains cemented by calcite, the latter occurring in irregular areas which are optically continuous. By treatment with acids, therefore, the graptolites may be completely isolated, and the following account details the process employed in the determination of the structure of *Glyptograptus tamariscus*.

The grit is trimmed as near the fossil as is deemed safe and then placed in strong hydrochloric acid for a week. Most of the calcareous matter by this time is dissolved, leaving a slightly incoherent mass of quartz grains, which is transferred to a paraffin-wax dish containing commercial hydrofluoric acid. After twenty-four hours the graptolite is isolated, then washed and placed for periods of five minutes in successively stronger and stronger mixtures of alcohol and distilled water until it is completely dehydrated. The alcohol is removed by soaking in either clove-oil or xylol, after which treatment the fossil is transferred to celloidin dissolved in clove-oil. A glass plate, about one inch square, is cleaned and covered by a thin layer of paraffin-wax; the specimen is removed to the plate, covered with celloidin and submerged under chloroform. The celloidin hardens in about one hour, and may be trimmed as much as possible before transference first to xylol and then to paraffin-wax,[1] which is kept melted in a water-oven. When the celloidin block containing the specimen is thoroughly permeated, it is placed in a dish and covered with paraffin-wax, which, on cooling, completely encloses the celloidin. The wax is then cut into a rectangular block, mounted on a carrier, and fixed in a microtome. The sections, which are obtained in a long ribbon, are permanently mounted on glass slides by the normal microtechnical method. Specimens may be sectioned as thin as 4μ, although 10μ is perhaps a more convenient thickness.

Wiman's researches on the structure of the graptolitoidea terminated in 1901, and although he had sectioned many dendroids, he actually microtomed very few diplograptids, because he was able to determine their partial structure by clearing the specimens with Schultze's solution.

Afternoon.

Excursions to (*a*) Wolvercote and Kistlington; (*b*) Culham, Abingdon and Radley.

Saturday, August 7.

Excursion to Aylesbury, Hartwell, and Wheatley. Luncheon with the Directors of Messrs. Itter's Brick Company, Ltd.

Sunday, August 8.

Excursion to Swindon, Faringdon, &c.

[1] Paraffin-wax which melts at 65 deg. is most convenient, but wax with a lower melting-point may be used in a cold room.

Monday, August 9.

9. Dr. G. W. Tyrrell and Dr. M. A. Peacock.—*Lava Structures in Iceland.*

Structures of the Palagonite Series :
- Globular basalts.
- Shattered basalts.
- Pseudo-agglomerate.
- *Agglutinate*, cf. Vesuvius.

Recent Lava structures :
- Helluhraun (= ropy lava) and
- Apalhraun (= block lava).
- Lava tumuli.
- Jointing of 'grey basalt' helluhrauns.
- Craters, Eldborg, Frostadarvatn, etc.

Fracture Structures :
- The Allmannagja, etc.

10. Dr. A. K. Wells.—*Variolites from Merionethshire.*

Some igneous rocks exhibiting pillow-structure and occurring in the Ordovician east of Rhobell Fawr, Merionethshire, have proved to be basalts in a better state of preservation than any other material from this region.

A series of sections cut from a pillow has enabled the course of crystallisation to be followed, there being a complete passage from devitrified glass through variolites to normal sub-ophitic dolerite.

The rocks were described, comparisons made with kindred types, and matters connected with affinities and nomenclature were discussed.

11. Prof. Kendall, F.R.S., and Prof. A. Gilligan.—*Underclays and the 'Growth in Place' theory of Coal Formation.*

12. Mr. F. B. A. Welch.—*The Geological Structure of the Central Mendips.*

The Central Mendips comprise a rectangular area roughly measuring eighty square miles, between the townships of Shepton Mallet and Cheddar on the east and west respectively.

The area has been mapped on the six-inch scale, applying Vaughan's zones, for the purpose of investigating the tectonics.

The Mendips consist of a ridge of Palæozoic rocks running W.N.W.—E.S.E. The structure is usually considered as a simple anticline ; but actually it consists of four major periclines arranged *en échelon*, whilst overfolding and thrust-faulting have played an important part in determining the present distribution of the beds.

In the Central Mendips the main hill-mass consists of the North Hill, Pen Hill, and Beacon Hill periclines, having cores of Old Red Sandstone age, with the Carboniferous Limestone Series succeeding.

North of Pen Hill is a large inverted block of beds, showing extensive overthrusting, which extends north to Emborough. Against the main hill-mass, on the south side, a large syncline is thrust, extending from Cheddar to Wells. At one point a 'window' occurs, revealing beds of the main hill-mass beneath the overthrust. A second parallel overthrust occurs at Ebbor, and remnants of this are seen in small hills north of Wells.

The inliers of Carboniferous Limestone age in the plain to the south point to considerable disturbance ; but, owing to the covering of Triassic strata, relationship to the main hill-mass is not clear.

Earth movements appear first to have acted from the south, causing a more or less east-to-west ridge. Pressure from the west followed, and buckled the previously formed ridge, the main disturbance being in the Pen Hill region. This, together with differential movement, due to relative resistance of the blocks, has caused the present distribution of beds.

13. Mr. S. W. Wooldridge.—*The Diestian Transgression in the London Basin and its Effect on the Geo-morphology of the North Downs and Chiltern Hills.*

At the Southampton Meeting the writer presented the results of work on the high-level Pliocene deposits in the central tracts of the London Basin. These were represented as slightly younger than the Lenham Beds and derived in part from the breaking down of the latter.

Further work shows that we may regard the Diestian sea as having been roughly co-extensive with the present London Basin as defined by the chalk escarpments. Diestian outliers are far more numerous on the North Downs than is generally recognised, and in all cases they rest on a wave-cut platform inclined gently northwards. Where the coastline lay south of the present escarpment, as in East Kent, this platform bevels the escarpment crest. In the area south of London, however, the coastline bent northward where the Downs are highest, and here the platform is a bench cut in the dip-slope and backed by higher ground near the escarpment crest. This higher ground is covered with relict masses of Blackheath Beds which clearly have never been disturbed by the waves of the Diestian sea. It is concluded that the low northward gradient of the Diestian base precludes the idea of any pronounced re-doming of the Weald in Pliocene times. The gradient is so low that it may be in great part original. A method of distinguishing any such original gradient, from the effects of subsequent tilting, will be indicated. Further, there was transverse warping of pre-Diestian date, but since the deposition of the Lenham Beds there has been no resumption of that movement.

The bearing of the facts elicited on the general problem of the denudation of the Weald and the amount of recession of the chalk and Eocene escarpments since Diestian times is also discussed.

The relations of the Lenham Beds on the Chiltern Hills are found to be closely similar to those displayed on the North Downs. Owing to severe glaciation and a consequent higher degree of dissection, the beds are not so fully preserved, but their existence can be demonstrated at many places. Moreover, by studying the profile of the inter-consequent ridges it can be shown that the Diestian bevel or bench is conspicuous throughout the area. As in the case of the North Downs, the Lenham Beds are absent from the highest parts of the dip-slope, the coastline lying to the south of the escarpment crest from the neighbourhood of Princes Risboro' eastwards to the Hitchin Gap. The data lend themselves to the same treatment as that applied in the case of the North Downs; longitudinal and transverse warping can be evaluated and the recession of the Eocene escarpment traced.

Attention will be directed to the possible westward extension of the Diestian gulf or channel and the general palæogeography of this phase of Pliocene time will be discussed.

14. Dr. George Slater.—*The Structure of the Disturbed Deposits of Möens Klint and Lönstrup, Denmark.*

Möens Klint.—The classical disturbances of Möens Klint extend for a distance of about four miles.

The disturbances may be divided into two groups, one north and the other south, separated by a basin of chalk containing drift. In each group the structure of the disturbed beds shows a localised and definite relationship to a nucleus or 'core' of chalk of asymmetrical or drumloid form, the two cores being referred to as the Slotsgavlene core to the north, and the Dronningestol to the south. Owing to the progressive moulding of lenticles of chalk over and against the flanks of the cores, these were ultimately converted into 'horsts.' Hence there is a development of thrust-planes in the beds flanking the limbs, these thrust-planes being associated with drift intercalated in the chalk. To the south of the Dronningestol area the thrust-planes are associated with seven squeezed chalk anticlines, each averaging 200 feet in height.

Fossil evidence proves that the transported chalk had been derived from more than one zone. The disturbances are local and superficial, and the structure agrees in principle with that of the Ipswich sections described at the Toronto Meeting, 1924, under the title 'Glacial Tectonics as reflected in Drift Deposits.' This type of

structure has been demonstrated experimentally by Prof. W. J. Sollas in his models of 'Pitch Glaciers.'

Lönstrup.—The cliffs S.S.W. of Lönstrup form a median longitudinal section through the Rubjerg Knude Hill, the coast scenery resembling that of the Cromer Cliffs. The disturbances extend from Grotten Point to Martörv Bakker, a distance of 2½ miles. The material involved consists entirely of drift of two types, clay and sand; but boulder clay associated with gravel and sand flanks the sides of the disturbed zone and is overlain by *Saxicava* sand and *Yoldia* clay. The undisturbed glacial clay is exposed between Det lille Blaa and Grotten Point, whilst the underlying deposit of Oeldre *Yoldia* clay outcrops in the disturbed zone at Stortorn Point.

The structure shows a progressive development when traced towards the N.N.E., *i.e.* in the reverse direction to that of movement, and may be divided into three zones:

(*a*) At the Martörv Bakker, where the disturbances were initiated, the arrangement of the sand and lenticles of clay is analogous to that of the englacial deposits in stagnant glaciers of Arctic type. The iceward limb displays evidence of much pressure, including the packing of clay lenticles into a minor 'horst.' To the N.N.E. of this 'horst,' sand predominates. In this zone the original stratigraphical relationship between the clay and sand is lost.

(*b*) The central area between Rubjerg Knude Fyr and Brede Rende may be described as a *Zone of thrust-planes.* Inclined wedges and lenticles of clay and sand form 'pairs of deposits.' The original stratigraphical relationship between the two is preserved, but adjacent 'pairs' are divided by thrust-planes, the 'pairs' being repeated many times, suggesting 'fish-scale' or 'imbricate' structure. The dip of the thrust-planes gradually increases until vertical, and the zone terminates in a clay 'horst' near Rubjerg Knude Fyr.

(*c*) *The Zone of squeezed anticlines.*—Between Maarup Kirke and Rubjerg Knude Fyr considerable pressure is shown. The 'roots' of at least four squeezed anticlines or overfolds occur, the upper limbs of each being a thrust-plane.

The structure differs from that of the Möen area in the fact that the beds have a uniform direction of dip to the N.N.E., but agrees with the phenomena seen at Möen on the iceward limbs of the 'cores.'

The Lönstrup sections represent the tectonics of a stagnant glacier as reflected in the lower englacial material.

The expenses of this investigation were defrayed by a grant from the Dixon Fund of the University of London in 1925.

AFTERNOON.

Excursion to Chawley and Boar's Hill.

Tuesday, August 10.

15. Mr. W. B. Wright.—*Stratigraphical Diachronism in the Millstone Grit of Lancashire.*

An examination of the marine bands of the Millstone Grits and Lower Coal Measures of the Rossendale Anticline by the Lancashire Unit of the Geological Survey has demonstrated on the whole the reliability of the zonal scheme established by Mr. W. S. Bisat. The goniatites, on which the system is based, being found only in thin bands at intervals throughout the succession, showed, at first, a fairly clear-cut subdivision into species. The development being only recorded at well-spaced intervals, there was no baffling continuity of evolution. When, however, as in the upper beds, continuous exposure over a wide area allowed of more extended study, considerable lateral variation became apparent. This became distressing when it amounted to a distinct departure from type, and even more so when it led to the replacement of one zonal form by another in the same marine band, thus giving the impression that the zonal scheme might be, as regards its details, of only local value. The subsequent discovery that the variation was systematic put a new aspect on the question, however, and it now seems as if what at first appeared a troublesome

anomaly may, on the contrary, prove a valuable weapon in the study of the evolution of the goniatites and in determining the conditions of deposition in the Upper Carboniferous delta. The state of things is best exhibited in the following table showing the south-westward variation in the two highest marine bands of the Millstone Grit Series :—

	SW. Bolton & Horwich	Rossendale N.	NE. Todmorden & Blackburn
Haslingden Flag Marine Band	G. listeri	G. listeri	G. cumbriense
		G. cumbriense	G. crenulatum
		G. crenulatum	
Holcombe Brook Marine Band	G. cumbriense	G. cumbriense (small, rare)	G. cf. crenulatum (rare
	G. crenulatum	G. crenulatum	G. cancellatum
	G. cancellatum	G. cancellatum	
Same, Bottomleaf.	G. cancellatum	G. cancellatum	Bed failing North
	R. ret^{m} mut. γ	R. ret^{m} mut. γ	

Now it is highly improbable that the successive members of a faunal sequence can, under uniform conditions, occupy portions of the same sea not more than twenty miles apart at one and the same time. One must rather, in view of the species always maintaining the same order of development, regard them as absolute indices of the passage of time, and if so there is no escape from the conclusion that the Haslingden Flag Marine Band was not contemporaneous in the north-east and south-west. The idea is not a new one and analogous phenomena are demonstrable in almost every highly fossiliferous formation. It is now proposed to introduce the term *diachronous* to describe a bed having such relations to the zonal succession. The word is self-explanatory and avoids a cumbersome circumlocution.

It will be noticed that the essential peculiarity of the Haslingden Flag Marine Band is that it drops zonal forms at the base as it takes others on at the top. The relations of the Holcombe Brook Marine Band are somewhat different. When traced south and west it takes on zonal forms both at top and bottom. It is diachronous as regards its upper and lower limits, but synchronous as regards its centre. The γ-bed below behaves similarly and actually dies out to the north-east. The sea in which the two last-mentioned marine bands were laid down advanced from the south and west and withdrew towards the same points of the compass ; that in which the Haslingden Flag Marine Band was deposited advanced from the north-east and withdrew to the south-west.

16. Miss Sibyl M. Hampton and Prof. H. L. Hawkins.—*A Revision of the Echinocystoida.*

Newly acquired material of the problematical genera *Echinocystites* and *Palæodiscus* has made possible some additions to our knowledge of the structure and affinities of these Silurian Echinoidea. It appears that *Echinocystites* is a thoroughly established and specialised Echinoid, and that in most respects it seems akin to the Lepidocentridæ. The new evidence points to its endocyclic character ; while the great development of its madreporite may be correlated with the complexity of its ambulacra as indicating vigorous use of the podia.

In the case of *Palæodiscus* it has been possible only to add a few details, but the discovery of several specimens which show the inner and outer aspect of the adoral surface helps in the interpretation of older material. The existence of perfectly typical Echinoid pore-pairs in the ambulacral plates (both coronal and peristomial) is confirmed ; and indications of structure can be detected in the so-called 'anal area.' Practically every detail of the lantern can be studied in an undistorted state.

In neither genus does the new material afford the slightest suggestion that there can be two series of ambulacral plates ; nor has re-examination of most of the material in older collections lent any support to that hypothesis.

17. Joint Discussion with Sections D and K on *The Conception of a Species.* Opened by Dr. F. A. Bather, F.R.S.

Other speakers : Prof. E. B. Poulton, F.R.S., Mr. A. J. Wilmott, Prof. H. L. Hawkins, Dr. C. Tate Regan, F.R.S., Prof. J. McLean Thompson, Dr. A. E. Trueman, Major C. C. Hurst.

Dr. F. A. Bather.—*Is the Species Concept of Value?*

The answer depends on what the species concept is. A species concept will always be necessary for practical convenience. The question is whether this practical species concept corresponds either to any grouping of the natural facts or to that grouping which we desire to emphasise. There is a concept towards which the facts of palæontology seem to impel us, and another concept deducible from facts of genetic experiment. Both may be true, as corresponding to certain realities, but it does not follow that either should oust the existing systematic concept.

Prof. Herbert L. Hawkins.—An analysis of the difficulties introduced by the nature of fossil material, and the consequent inevitable differences between the palæontological and neontological view of a species.

The contrasted attitude of the stratigrapher and the palæobiologist.

Problems raised by chronological sequence and complicated by palæogeographical characters. Continuity and convergence in evolution show the artificiality of classification, and make difficult the selection of an arbitrary basis for it. The introduction of structures of prime physiological importance seems fairly rapid, and such episodes might furnish the framework of a systematic scheme. But from the neontologists' standpoint such changes would mark generic or higher grades of classification.

In palæontology the genus must be the unit; the so-called species (when not of generic rank or representing groups known very inadequately) are indefinite sections of continuous lineages.

Prof. J. McLean Thompson.—The present conception of a species is based primarily on the characters of the adult organism. Such characters are more readily observed than understood. An attempt will be made to show that by an ontogenetic study new light is thrown on specific characters as to their time of declaration during development and as to their interpretation. By this means a re-valuation of specific characters may be obtained.

Dr. A. E. Trueman.—The problems of species-nomenclature in palæontology are perhaps most complicated in the case of those invertebrates which occur abundantly at many horizons, and which exhibit wide variation at each horizon. This is especially true if specimens at one horizon differ among themselves in the stages attained in those characters in which the stock is progressing; in such cases, although the average degree of progress will be greater at a higher horizon, individual specimens may be indistinguishable from certain of those at the lower horizon.

Statistical investigation of extensive series of *Carbonicola* and *Anthracomya* (Coal Measures) and *Gryphæa* (Lias) shows that the variation at any horizon is continuous, that each community is homogeneous and indivisible, and that the unit-characters, on the whole, vary independently. Such a ‘ community ’ may perhaps be compared with an ‘ impure species ’ or a group of more or less freely interbreeding individuals with interwoven pedigrees. Nevertheless, the variations within the group are not sharply separated as in Jordanons, but merge continuously into one another.

It follows therefore that such an evolving stock must be regarded as a ‘ plexus ’ or a bundle of anastomosing lineages. A species can only be regarded as a fixed point in such a plexus, and a specific name should only be applied to those specimens which agree with the type in all determinable characters. Any other application involves division into unnatural groups.

Major C. C. Hurst.—Recent genetical experiments and cytological observations have given a more precise definition of a species. A species is a group of individuals of common descent with certain constant characters in common represented in the nucleus of each cell by constant and characteristic sets of chromosomes. Two thousand eight hundred and forty-five species of plants and animals, including representatives of all the Phyla, so far examined, show remarkable constancy in their specific sets of chromosomes.

In the polymorphic and polyploid genus *Rosa*, specific sets are composed of seven chromosomes (septets). Five differential septets have been identified, and their various paired combinations make thirty-one regular species possible (five diploids and twenty-six polyploids); twenty-three of these have been found, leaving eight to be discovered.

Irregular polyploids with unpaired septets have the same mechanism. Thus, a species is a precise taxonomic unit subject to experimental verification. Genetical species are homozygous for specific characters and heterozygous for sub-specific and varietal characters, being taxonomically equivalent to Linnean species.

AFTERNOON.

Excursion to Headington and Shotover.

Wednesday, August 11.

18. Prof. W. L. BRAGG, F.R.S.—*The Relationship between Orthosilicates and Metasilicates.*

Several types of the less complex natural silicates have recently been analysed, Amongst them are included Zircon $ZrSiO_4$, Garnet $Ca_3Al_2Si_3O_{12}$, Olivine Mg_2SiO_4. Monticellite $MgCaSiO_4$, Beryl $Be_3Al_2Si_6O_{18}$, Phenacite Be_2SiO_4, Topaz $(AlF)_2SiO_4$, Chondrodite $Mg_3\ (MgOH)_2\ (SiO_4)_2$. To this list should perhaps be added the various forms of silica SiO_2, analysed by W. H. Bragg and Wyckoff, because of the relationship between them and the silicates.

The number of structures yet known is small, and generalisation premature. It is interesting, however, to examine a few features of these structures on account of the importance of this group of compounds.

There is justification for the view that the silicon plays the part rather of a metal in a complex oxide than of the nucleus of an acid radicle. The structure of the olivine group (Mg_2SiO_4, &c.) is identical with that of chrysoberyl $BeAl_2O_4$. The latter is a typical metallic oxide, closely related to spinel $MgAl_2O_4$, and corundum Al_2O_3. In all these structures the oxygen atoms are in approximate close-packing, as though the repulsions between these atoms decided the shape and size of the structure, and the very much smaller metal ions are inserted into the interstices of the tightly packed oxygen atoms. In fact, the dimensions of the close-packed oxygen structure can be traced throughout the following series of compounds, in order of complexity—BeO, Al_2O_3, $BeAl_2O_4$, Mg_2SiO_4, $MgCaSiO_4$, $(AlF)_2SiO_4$, $Mg_3\,(MgOH)_2\,(SiO_4)_2$. The replacement of a metal by silicon does not break the continuity of the series.

Beryl, $Be_3Al_2Si_6O_{18}$, has the composition of a metasilicate. Examination shows that there are no groups of form $SiO_3{}^{=}$ in the crystal, like the very definite $CO_3{}^{=}$ groups in a carbonate. Instead, each silicon is surrounded by four oxygen atoms in beryl as it is in every other silicate as yet analysed, and the correct proportion of oxygen to silicon is obtained by a sharing of oxygen atoms between neighbouring SiO_4 groups.

The structures of garnet and phenacite are again of the 'co-ordination' type, like spinel and chrysoberyl. In all these silicates the oxygen atoms take up the greater part of the volume of the structure. They are bound together by atoms of the metals and silicon. The silicon is at the centre of a tetrahedral group of four oxygen atoms, and the metal at the centre of a similar tetrahedral group or of six oxygen atoms at the corners of an octahedron. All are typical co-ordination structures.

19. Prof. G. HICKLING.—*Graphical Studies of the Relations of Peat, Coa and Anthracite.*

The author has made an attempt to ascertain the relation between the various types of coal by graphic representation of the distribution of the chief elementary constituents (C, H, O, N, S) in some 1,500 coals of all types. The principal constituents have been plotted one against another in pairs (C : H, C : O, &c.), the 'dry, ash-free' analyses being employed in all cases. The analyses of the U.S. Bureau of Mines are particularly adapted to the purpose, and have provided the greater part of the material.

By this method it is reasonable to suppose that any groups of coal derived from parent-material of exceptional composition, or which have undergone different lines of chemical alteration, will be distinguishable as separate groups on the graphs.

The results are strikingly of the opposite tendency. All the normal lignites, coals and anthracites (excluding the cannel group) form a single continuous series with a very long range of composition. There is no sign of more than one general line of chemical alteration, or of more than one general type of parent material. It is suggested that the graphs give very strong support to the view that the chief grades of normal coals owe their main distinctive features to varying degrees of alteration.

The distinct character of the cannels is readily seen.

The method throws some light on the nature of the chemical changes produced at successive stages.

20. Dr. H. M. Ami.—*The Cambrian Fossils of Canada, and the Remarkable Faunas they represent.*

21. Mr. A. W. Coysh.—*The Petrology of the Avonian Rocks at Sodbury, Gloucestershire.*

The Lower Carboniferous succession in the Sodbury railway-cutting has been investigated from a petrological standpoint.

The insoluble residues from the limestones have been examined microscopically, yielding interesting results.

Three '*Modiola*-phases' occur in the sequence, in Km, C_2 and S_1, and S_2. They include a good deal of sandstone, especially in S_1 and S_2, which has yielded magnetite, rutile, zircon, ilmenite, tourmaline, muscovite, and staurolite among its rarer constituents.

The significance of this assemblage is discussed, and the probable conditions of deposition of the rocks are dealt with, field evidence being described.

22. Dr. K. S. Sandford.—*Preliminary Remarks on Early Man in relation to River Gravels and other Deposits of Upper Egypt.*

Pre-Pleistocene limestones, travertines, marls and conglomerates have now been traced in almost unbroken continuity in the Nile Valley from a point south of Luxor nearly as far north as Assiut and up the great Wadi Keneh towards the Red Sea Hills; they rise to a height of 200 ft. or more on the valley sides. In them are cut the great river-terraces, of Pleistocene age, in the Nile Valley and W. Keneh (which carried a very heavy run-off from the Red Sea Hills to the Nile). Study of these terraces and their gravels over a wide area has led to the discovery of worn and unpatinated implements in them, as well as surface sites upon them. The preliminary sequence arrived at (levels approximate) is:—

100-ft. terrace containing rolled Chellean implements.
50-ft. ,, ,, ,, Acheulean ,,
10-ft. ,, ,, ,, Mousterian ,,

There are other intermediate terraces, in particular one at 25-30 ft. which contains rolled Acheulean implements, with surface working sites of Mousterian age (the implements thus occurring at the foot of this terrace, rolled, in the 10-ft. terrace). There is a buried channel of the Nile, of which the depth is unknown.

North of Luxor igneous material from the Red Sea Hills is a typical constituent of the Nile gravels.

The terraces mark 'pluvial periods,' which have now been 'dated' by the implements, and they are likely to prove of great significance.

The work was carried out by camel reconnaissance under the auspices of the British School of Archæology in Egypt, vital assistance for the desert journeys being given by Dr. W. F. Hume, Director of the Geological Survey of Egypt, and Dr. Ball, Head of the Desert Survey.

23. Mr. Maurice Black.—*The Structure and Conditions of Deposition of the N.E. Yorkshire Estuarine Series.*

The Estuarine Series of N.E. Yorkshire consist in the main of inconstant though level-bedded strata, but at some horizons intense current-bedding is found as a result of the prolonged action of shifting river-channels. The sequence of Middle Jurassic

is interrupted by erosion and channelling at several well-marked levels, which are frequently characterised by systems of washouts.

At the base of the Upper Estuarine Series there is evidence of a shallow sea giving place through phases of delta growth and shallow fresh-water lagoons to conditions of delta-swamps, and the preserved fossil floras are seen to change with the altering conditions of deposition. The characteristics of plant-beds which represent floras growing in place on the delta are quite distinct from those of beds made up of drifted fragments.

SECTION D.—ZOOLOGY.

(For references to the publication elsewhere of communications entered in the following list of Transactions, see page 445.)

Thursday, August 5.

1. Prof. H. F. Osborn.—*The Problem of the Origin of Species as it appeared to Darwin in* 1859 *and as it appears to-day.*

In the years 1837 to 1859, when Darwin was writing the 'Origin of Species,' there still prevailed the zoology of Linnæus and Buffon and the palæontology of Cuvier. The number of mammalian species is estimated at 1,200, as compared with the 12,500 species and sub-species known at the end of the year 1924. Darwin's species stood out like isolated mountain-peaks, whereas to-day living species are often comparable to mountain-chains composed of lesser peaks completely connected by ridges known as intergradations. Similarly, the few extinct species known in Darwin's time are now recognised as terminal stages of often continuous 'descending mutations,' species, genera, and sub-species reaching through hundreds of thousands, if not millions, of years. Thus in both zoology and palæontology we observe continuity, where Darwin observed discontinuity; consequently, in 1926 the problem of the 'origin of species' is absolutely different from what it was in 1859.

Of the vertebrate class, with which we are most familiar, it may be said briefly that the *modes* of the origin of species are now thoroughly well known, while the *causes* of the origin of species are far more obscure than in Darwin's day. As to the modes, we may compare all that we may observe in nature as to fishes, amphibians, reptiles, birds and mammals, living and extinct, and we find that several great principles governing the origin of species emerge from this comparison, chiefly through the testimony of naturalists who have been observing on a world-wide scale, as Darwin himself began to do in the voyage of the *Beagle*. Similarly, we assemble the observations of palæontologists working on a world-wide scale, especially in the now wonderfully complete succession of mammalian life during the Tertiary period. In both zoology and palæontology these observations include intensive examination of meticulous changes in form, colour, anatomy and habit; there is also intensive observation of chemical, physical and living environment and of habit, and, in certain cases, of heredity—these being the four coefficients of the origin of species.

The outstanding conclusion from this comparison is that species originate through a continuous and creative adaptation in either stable or changing conditions of environment. The word 'creation' must certainly be linked with the word 'evolution' to express in human language the age-long origin of species.

2. Dr. Heslop Harrison.—*Induced Mutations and their Significance in Evolution.*

In the industrial areas both on the Continent and in the British Isles melanic forms have arisen in many lepidopterous species. Careful observations made in such districts suggest at once that impurities in the way of metallic salts thrown into the atmosphere as a result of industrial operations are responsible for the phenomena, and, furthermore, that they exert their influence on insects in the larval condition by means of their food-plasts.

It ought therefore to be possible to induce melanism in susceptible groups, (1) by feeding non-melanic strains on food-plasts gathered in melanic stations, and (2) by rearing such strains in non-melanic areas on food-plasts artificially charged with

impurities known to be present in or on the foliage of plants in manufacturing districts. Both methods were adopted, the species used being *Selenia bilunaria* Esp., *Tephrosia bistortata* Goeze and *T. crepuscularia* Bkh., and the salts manganese sulphate and lead nitrate. Small numbers of melanics appeared in all the experimental cultures, and the melanism so induced proved to be inherited as a Mendelian recessive in the case of *S. bilunaria* and *T. bistortata* and as a dominant in *T. crepuscularia*.

The results are of extreme importance from an evolutionary point of view by demonstrating that the germ-plasm can be affected by environmental influences. In addition they afford a ready explanation of the origin of local races, of the evolution of closely allied species of insects with distinct food-plasts, of the break of domestic animals and plants into distinct breeds, and of other similar occurrences.

3. Dr. H. Eltringham.—*Butterfly Vision.*

The structure and function of faceted eyes. The Mosaic theory of insect vision. Pseudocone and eucone eyes. Exner's explanation of the action of the compound eye. The superposition and apoposition images. The Glow-worm's eye. The eyes of Flies and Dragon-flies. The structure and action of the Butterfly's eye. Its erect image. Can Butterflies distinguish colours? Description of experiments designed to solve this problem. The question of ultra-violet light. Conclusions.

4. Prof. W. C. McIntosh, F.R.S.—*The Structure of the Operculum in Mercierella and allied forms.*

The peculiar aspect of the operculum of *Mercierella*, which at first sight suggested opercular development, led to the following inquiry in specimens provided by Mr. Carmichael Munro, of the British Museum, from a series sent by Mr. Charles Major, on whose barge they occurred. In the original account by Prof. Fauvel no allusion to the internal structure was made, nor was this dealt with in Mr. Munro's remarks on the British form.

In Prof. Fauvel's subsequent remarks the masses of blood contained in the operculum were considered to be mucus. The present inquiry shows that the operculum and its stalk in *Mercierella* have a chitinous layer externally, then a layer of hypoderm which thins off as the operculum is reached, whilst internally the centre of the stalk has the blood-vessel and a series of fine reticulations which somewhat increase in size as they approach the operculum, in which they enlarge into great blood-spaces. The blood, which is greenish in most Serpulids, readily forms isolated masses which stain deeply. The opercular stalk, which is morphologically a branchial filament, is contrasted with these organs and the modifications demonstrated, as well as the presence of remarkably elongated terminal processes to each filament. The structure in *Mercierella* is then compared with that in various Serpulids such as *Ficopomatus, Hydroides, Serpula vermicularis, Pomatocerus, Spirorbis* and others in which an approach to the condition in *Mercierella* occurs, and the importance of the operculum in relation to the circulation, and perhaps in certain forms to respiration, indicated.

The new British Polychæt which was sludged by Prof. F. J. Cole, of Bristol, near Port Erin in the Isle of Man, is closely allied to *Amœa trilobata*, one of the many discoveries made in northern waters by the elder Sars; but whilst agreeing in general structure with this species, it presents certain divergencies—if the descriptions and figures of Malmgren can be relied on. Thus the oval folds form dorsally a deep frill which curves ventrally on each side to form two parallel flaps that pass outward in front of the first segment as large lamellæ beset with numerous small tentacles as in the type. In *A. trilobata*, instead of the frill, a median tongue-like process occurs on the ventral surface, the anterior edge of the dorsal collar is smooth, and a simple transverse segment lies behind the lateral lamellæ, whereas in the British form there is a thick curved arch or ridge. Moreover, instead of the median groove anteriorly on the ventral surface of the British form, there are five scutes in the Norwegian. The bristles, so far as they occur in the injured example, agree with the type.

5. Reports of Committees.

6. Dr. F. A. Dixey, F.R.S.—*Lecture on Recent Criticisms of the Theory of Mimicry.*

Friday, August 6.

7. Joint Meeting with Section I for papers on *Tissue Culture.*

Dr. H. M. Carleton, Prof. Ch. Champy, Dr. H. B. Fell, Mr. E. M. Wilmer.

Prof. Ch. Champy.—The method of tissue culture, first introduced by Ross Harrison and then perfected by Carrel, has become an integral part of cellular biology. There are to-day many different methods for the cultivation of tissues. This is because each one has been evolved with a different aim in view. Cultivation in plasma, *i.e.* in one of the body's own fluids, is the best technique for the study of certain problems in embryo-mechanics. The addition of embryonic extract facilitates both the isolation of pure strains of cells as well as the prolongation of life *in vitro*. Methods involving the use of simple inorganic media are useful for cytological studies, while the use of such media, to which nutritive substances have been added, permits of researches on the nutritional conditions of cells.

It is particularly important clearly to define certain terms. 'Cultivation' should only be applied to tissue cultures which show division of cells; 'survival' should be used only in the sense of living cells undergoing modification without cell-division (as in the case of nerve-cells).

It is a pity that the word survival has been applied to tissue cultures in a derogatory sense. The value of a method is proportionate to the scientific value of the results furnished by it. Ross Harrison's fundamental researches on the nerve-cell *in vitro* were only survival experiments. Yet they furnished a result of greater scientific value than have the majority of the experiments on tissue-culture done since then.

My first researches were intended to verify Carrel's results. From the outset I was struck by the fact that the newly formed tissues were histologically very different from the tissues in the original fragment. As the tissues extirpated from the body multiply, so do they progressively lose their previous specialisation. To this phenomenon I applied the term 'Dedifferentiation.' Kidney-tissue in culture shows a particularly marked example of this phenomenon. Smooth muscle and ovarian and uterine epithelium also show it.

By 'dedifferentiation,' however, I do not mean that the newly formed cells are totally different; certain features persist. Nor do such cells lose all potentiality of differentiation; for instance, connective-tissue cultures, if grafted back into the organism, again form collagen fibres. Another feature of certain tissue-cultures is their resemblance to malignant tumours, for the latter also have dedifferentiated, although they still retain certain of the features of the tissues from which they sprang. An interesting fact in cultures made from adult organs in which mitoses are not present (*e.g.* kidney, smooth muscle, thyroid and neuroglia) is the abrupt reappearance of mitoses in the cultures.

The study of regeneration in the living organism appears to show that it is conditioned by factors similar to those which operate on the extirpated tissues *in vitro*. There is also a large field for study, by alternating certain of the constituents of the medium, of the nutritional requirements of cells.

The mutual effects of tissues on each other can also be studied in tissue-cultures. This has already been done with interesting results in the case of epithelium and connective-tissue. And, finally, the fact that cells can be caused to multiply (apparently indefinitely) *in vitro* and that in so doing they come to resemble tumour cells is, to say the least, suggestive.

Dr. H. B. Fell.—The method of tissue-culture *in vitro* is peculiarly favourable for the experimental study of certain problems of vertebrate embryology. It is especially valuable as a means for investigating the capacity of isolated embryonic organs and fragments of organs for self-differentiation. By incubating an embryonic organ or fragment of organ in a culture-tube containing a relatively large volume of plasma and embryo extract, it is possible to study the growth and differentiation of the tissue when it is completely isolated from its normal environment and deprived of all nervous and vascular connections. It has been found that embryonic avian tissue growing under such conditions shows a remarkable capacity for normal differentiation, and in favourable specimens exhibits comparatively little cellular degeneration; growth, however, is greatly retarded and extremely restricted.

8. Presidential Address by Prof. J. Graham Kerr, F.R.S., on *Biology and the Training of the Citizen.* (See p. 102.)

9. Dr. R. T. Gunther.—*A New Sense Organ in Siphonophora.*

The material investigated was sent home by Dr. Gilchrist from the Cape of Good Hope for examination in the Daubeny Laboratory.

The new organ was observed in a series of swim-bells from the nectosome of *Crystallodes vitrea* of Haeckel, a member of the Agalmid group of Siphonophora, well known for their perfectly co-ordinated powers of swimming and for their remarkable crystalline forms. In them the cavity of the swim-bells is prolonged into two horns, ensheathed in a special musculature, the apparent purpose of which is to direct the expelled water to one side or to the other, and thus to steer the animal when swimming. Experimental evidence as to this function has been obtained with living Halistemma at Naples. In Crystallodes the circular muscles round the horns of the bell-cavities were seen to be connected by two nerves to two symmetrically dispo ed diverticula projecting from the lateral gastrovascular canals into the jelly body. These have not hitherto been described, though in the youngest swim-bells near the apical air-sac they are relatively quite large and easy to see. In the older swim-bells they are reduced to mere pin-points. It is suggested that these organs serve as differential pressure gauges, and that it is by their means that the directive propulsive mechanisms of the animal are regulated.

10. Dr. R. T. Gunther.—*The Collections of the Tradescants, Poynter, Dyer, and Clutton.*

These very early collections of objects of Natural History, though greatly reduced by neglect, not only include some of the oldest museum specimens known, but, taken together, illustrate in a unique manner the early history of museums in Great Britain. A few of the specimens that have survived the wear and tear of centuries have now been brought together for the first time in our oldest public-museum building.

1. The *John Tradescants*, father and son, collected from 1627 to 1656. They founded the first London museum at Lambeth, and by their endeavours provided an incalculably great incentive to the exploration of the world by stimulating traders and travellers to take stock of the interesting and valuable produce of foreign countries.

The contents of their museum were transferred to the Old Ashmolean Museum in Oxford in 1683, where they remained until 1860, when they were scattered. The gradual process of destruction of the historic specimens has been continued almost to the present day, and unless special care be taken of the few specimens that remain more will disappear. The specimens still extant represent some fifty species of animals, and in the opinion of many authorities should once more be brought together and be conserved as a collection.

2. *John Poynter*, chaplain of Merton College, made a general collection of naturalia, animal, vegetable, and mineral, for the purpose of illustrating his lectures to his pupils. It is probably the oldest *teaching collection*, and without equal in Britain. Since about 1730 it has been in the possession of St. John's College, and although many specimens have perished, it has been possible, by good fortune, to save the remainder, in the original drawers. Of unique interest are the series of British birds' eggs representing some forty species, perhaps the only evidence for the existence of certain varieties of colour markings as long ago as the year 1700 ; a series of the rocks of Shotover Hill, perhaps the oldest stratigraphical collection of rocks now preserved to us ; typical series of minerals, fossils, and botanical specimens. The latter include an early series of Barbadian nuts and seeds given by *Edward Dyer*, a highly skilled botanist, fellow of Oriel College, 1673.

3. The *Clutton* collection usefully supplements available scientific evidence as to the species of animals and plants used in medicine at the beginning of the eighteenth century. Other old collections of materia medica are less complete, or are not beyond suspicion, including substituted specimens of recent date.

Joseph Clutton, an apothecary of repute living at the Turnstile in Holborn, sold the entire collection of 1,032 specimens in a cabinet in 1729 to a Thomas Jobber for £21 6*s.* 8*d.* It became the property of New College at the death of Warden Oglander, and has been in cold storage in the muniment-room of that college ever since.

The specimens, including some sixty animals or parts of animals used in medicine, are thus close on 200 years old.

It has long been realised that museums impart knowledge with a precision and vividness which no mere literary description can give. These old Oxford collections, though few in number and diminutive in size, were made by the pioneers of the premier educational method of the science museum. They alone of many larger collections that have been destroyed now illustrate the early history of museums in Great Britain. Their adequate exhibition to the public in our own time, and a guarantee for their preservation for study by future generations, are therefore matters of paramount importance. Members of the British Association are invited to inspect them in the oldest public museum of natural history, in the Old Ashmolean building in Oxford.

Department I.*

* Section divided.

11. Dr. A. J. Grove and Mr. L. F. Cowley.—*On the Secretion of the Cocoon in Eisenia fœtida, the Brandling Worm.*

The freshly deposited cocoon of *E. fœtida* consists of (1) an enveloping transparent mucilaginous slime-tube, (2) a semi-transparent cocoon membrane, and (3) the albuminous contents.

Grove (*Q.J.M.S.*, vol. 69, 1925, p. 274) described in the clitellum of *L. terrestris* three different kinds of glandular elements. In *E. fœtida* the same three kinds of glandular elements have been distinguished, and by differential staining of sections of worms killed during the process of cocoon formation it has been possible to demonstrate that the three glandular elements produce respectively the three constituents of the cocoon. Thus the slime-tube is produced by the mucin cells; the cocoon membrane by the large granule glands; and the albuminous contents by the deep-seated fine granule glands.

12. Mr. B. N. Schwanwitsch.—*Evolution of Wing-pattern in Butterflies.*

13. Dr. G. D. Hale Carpenter.—*Mimicry in Relation to Geographical Distribution in the Ethiopian Nymphaline Butterfly 'Pseudacræa eurytus.'*

Pseudacræa eurytus was known to Linnæus in 1758. The type has a simple pattern, very dark brown and orange in the male, black and white in the female. It belongs to a genus related to the 'White Admiral,' and frequents forested or thickly bushed country: the flight is floating and the butterfly shy.

Numbers of butterflies have been described as species of *Pseudacræa*, sometimes with sexes alike, sometimes with sexes so different that males and females were described as distinct species. In 1912 breeding confirmed what was suspected on anatomical grounds, that the majority of 'species' of *Pseudacræa* are forms of one species (*eurytus*) found throughout the forested country in Africa from S.W. Abyssinia on the north to Pondoland in the south, and from the west coast to Mombasa. This note is intended to direct attention to an exhibit of forms assumed by this remarkably polymorphic species, whereby the public for the first time can realise the diversity induced by the appearance of other species not closely related. Every form of *eurytus* shown resembles an Acræine butterfly of genus *Planema*, sex for sex. Where the *Planema* has sexes alike the *Pseudacræa* is monomorphic; where the *Planema* is dimorphic Pseudacræas are found each resembling the appropriate sex of a *Planema*. On certain islands of Lake Victoria, when Planemas were scarce, forms of *eurytus* abounded showing variations transitional between the usual well-marked forms. The interpretation of these facts is that the Planemas, belonging to a sub-family known to be distasteful to insectivorous vertebrates, are copied by the Pseudacræas. The former are termed 'Models,' the latter 'Mimics.'

Mimetic resemblance is produced by natural selection working on the variations of *eurytus*. In the presence of *Planema* those variations have the best chance of surviving which most closely resemble the models.

14. Mr. R. C. Fisher.—*Recent work in France on Parasitic Control of Insects.*

A visit during 1925 to entomological laboratories in France afforded an excellent opportunity of observing in one country two aspects of the work involved in the use of parasites for the control of exotic insects.

1. *Study and Collection of Parasites in Country of Origin of Host Insect.*

At Hyères, the U.S. Bureau of Entomology has established a parasite laboratory for collection and study in Europe of the parasites of the European Corn-borer, *Pyrausta nubilalis* Hb., injurious to maize crops in the United States. A study of the parasites of this insect has been made in selected localities representative of varying climatic and other conditions in France and Central Europe. Consignments of parasites have been shipped to the United States for rearing and liberation in the field. A collection was made at Bergamo, Italy, in August 1925.

2. *Colonisation and Distribution of Introduced Parasites.*

At Mentone, the French Ministry of Agriculture has established an insectarium for the rearing and distribution of imported insect enemies of scale insects, e.g. *Icerya purchasi* in particular, *Dactylopius, Pulvinaria* and *Pseudococcus* spp.

Acclimatisation of *Aphelinus mali* for the control of the apple woolly aphis—*Eriosoma lanigera*—is being continued in different parts of France with varying results.

The present trend of research on parasites in France is to study the entire parasitic complex of one particular host-insect. Work on these lines has been carried out for *Pieris brassicæ* at Lyons. The parasites of other injurious insects might very profitably be studied in a similar way. The relations and interrelations of host and parasite, of parasite and parasite, in localities differing in climatic and ecological conditions, would yield a true indication of the rôle played by parasites in the control of any insect in its natural habitat. Such should, theoretically, be known before parasites are introduced from one country into another.

Department II.*

* Section divided.

15. Prof. F. H. Edgeworth.—*The Morphology of the Eye Muscles in Lower Vertebrates (demonstration of models showing development of the Skull in Acipenser and in the Ganoids).*

In Dipnoi, Urodela, and Anura all the external ocular muscles are developed from the walls of the first head cavity or homologous primordium. This is probably their primary origin.

In certain Teleostomi the recti superior, internus and inferior, and the obliquus inferior are developed from the walls of the first head cavity. The obliquus superior and rectus externus are developed from the distal and proximal portions of a projection from the upper end of the mandibular muscle-plate. In Plagiostomi the recti superior, internus and inferior, and the obliquus superior are developed from the walls of the first head cavity. The obliquus superior and muscle E are developed from the distal and proximal portions of a projection from the upper end of the mandibular muscle-plate. Muscle E fuses with an anterior projection from the upper end of the hyoid muscle-plate to form the rectus externus.

The conditions in Teleostomi and Plagiostomi may be considered secondary and tertiary modifications of those in Dipnoi, Urodela and Anura.

These conclusions are in harmony with observations already published showing that the masticatory muscles of Dipnoi and Amphibia are more primitive than those of Teleostomi and Plagiostomi.

Muscle E of Plagiostomi is probably either homologous or homoplastic with the rectus externus of Teleostomi—according to the presumed ancestry of the latter group.

The absence of any (subsequently atrophying) primordia separating from the upper ends of the mandibular hyoid muscle-plates in Dipnoi, Urodela and Anura, and of any such primordium from the hyoid muscle-plate in Teleostomi, casts doubts on V. Wighe's theory that the primordia of the obliquus superior and rectus externus of Plagiostomi represent præotic myotomes.

16. Prof. W. D. Henderson.—*The Morphology and Development of the Hyomandibula in Fishes.*

The paper deals with the development of the hyomandibular cartilage in fishes. The development has been studied in several specimens of each group, and a summary of the facts as given in previous work has been made. The relation of the nerves, blood-vessels, and muscles to the cartilage in the various groups has been traced. The position of the articulatory facet on the walls of the otic capsule has been followed in the various forms, as some of the newer views have been based mainly on this in discussing the homology of the Hyomandibula. No trace of a double head has been found in any of the specimens examined, so that there seems to be little support for the view that the foramen for the R. hyomandibularis facialis is the result of the fusion of two cartilages. The views of Allis, Schmalhausen, and de Beer are discussed in relation to the points found in the specimens studied and also in connection with the accounts given by previous workers.

17. Mr. G. Leslie Purser.—*On some interesting Morphological Features of Calamöichthys.*

(*a*) The dentition shows a significant intermediate condition between those with many rows of functional teeth and those with but one.

(*b*) The sharp change-over from an ectodermal to an endodermal type of epithelium at the level of the glottis casts doubt upon the present-day view of the germ-layers at the beginning of the alimentary canal. What is our basis upon which we decide homology?

(*c*) The whole of the blood from the last gill-arch and part from the last but one passes directly to the lung of the same side. The structure of the wall of the latter is confirmed to be respiratory. Asymmetry of the lungs, both as regards size and relationship to one another, indicates that the left one is really a diverticulum from the originally median and single right.

(*d*) The venous system exhibits at least one very important series of peculiarities: there is a well-developed posterior vena cava, though its origin is farther back than is usual; and the posterior cardinal veins are very asymmetrical, as the left is reduced to an azygos, while the right remains large and serves both sides of the body posteriorly.

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18. Dr. D. Hutchinson.—*Amœba (Cinematograph film).*

Saturday, August 7.

Excursion to Tring.

Monday, August 9.

19. Dr. G. D. Hale Carpenter.—*Lecture on some of the Problems connected with Sleeping Sickness.*

Sleeping Sickness must not be confused with *Encephalitis lethargica*, or 'Sleepy Sickness.' It is a disease of tropical Africa caused by a flagellate protozoon (*Trypanosoma*) transferred by Tsetse flies of the muscid genus *Glossina*. Several closely allied forms of *Trypanosoma* found in animals and man cause 'fly disease' of cattle, or 'Nagana,' and Sleeping Sickness. One of the problems discussed is whether *T. brucei* of 'Nagana' is essentially the same as, and can become, *T. gambiense* of Sleeping Sickness, and whether *T. rhodesiense*, causing a more acute disease in man, is derivable from *brucei* or/and *gambiense*. Possibly the nature of these Trypanosomes depends largely upon the mammalian host rather than upon the species of *Glossina* transmitting them, but the method of transmission may have much to do with the degree of virulence.

Trypanosomes mechanically transmitted on the proboscis of *Glossina* seem more virulent, while the developmental processes in *Glossina* whereby Trypanosomes are injected in the salivary secretions seem to reduce virulence.

An important problem is whether other insects than *Glossina* transmit Sleeping Sickness. From the point of view of habitat there are two main types of *Glossina*,

those frequenting the neighbourhood of water in heavy shade (e.g. *G. palpalis*) and those found in more open bush-country (e.g. *G. morsitans*). It is misleading to talk of '*The* Tsetse-fly problem'; there are two, and the problems of attacking each group differ greatly.

One of the greatest problems is whether big game is a danger, since Trypanosomes found in them are apparently indistinguishable from those causing Sleeping Sickness. The problem can only be solved by experiment on a volunteer, but there is evidence that prolonged sojourn in an antelope renders the Trypanosome less able to live in man, so that big game may be beneficial rather than harmful.

20. **Discussion** on *The Training of a Zoologist.*

Prof. J. H. Ashworth, F.R.S., Prof. W. J. Dakin, Prof. Julian Huxley.

21. **Joint Discussion** with Sections H and J on *Heredity in its Physical and Mental Aspects.*

Dr. C. S. Myers, F.R.S., Prof. R. Ruggles Gates, Mr. R. N. Salaman, Mr. T. Cooke, Prof. Julian Huxley, Dr. F. A. E. Crew.

Dr. C. S. Myers.—Heredity has been viewed from two standpoints—the physical and the psychological. According to the former, definite units of 'behaviour' exist, and these are separately localisable in different structures within the germ-cells, much as various mental functions are commonly supposed to be localisable in different regions of the cerebral hemispheres. Adoption of the psychological standpoint, on the other hand, has resulted in vague and otherwise unsatisfactory analogies being drawn between heredity and memory. It is my object here to suggest that other and more valuable psychological considerations may be utilised, and that the final solution of the nature of heredity lies in a combination of *both* standpoints.

The physical standpoint must naturally be confined to a purely mechanistic explanation. But this can only be one aspect of the entire truth. What is found in mind must also occur in life. Blind mechanism is a mere abstraction from the whole. The purely mechanical reflex is rarely a separate entity in the intact organism. So, too, instinct and genius are inseparable (save by abstraction) from intelligence. Orderly, purposeful direction, however rudimentary, is universal in the creation of the new.

Because a certain area of the cerebral hemisphere must be intact in order that a certain kind of consciousness may occur, it does not follow that that area is the *seat* of that kind of consciousness. We are only justified in concluding that a necessary condition for a special kind of consciousness to appear is that the corresponding nervous processes must pass through a special area of the cortex. The localisation of inherited qualities in chromosomes may have merely a similar implication.

At all events what is obviously inherited seems something more akin to mind than to matter; the functioning of the whole and the interrelation between parts, general orderliness, and direction seem at least as important as a narrow material localisation. It is in the persistence of these rather than in its identical substance that the 'immortality' of germ-plasm consists.

Here enters the difference of attitude between the physicist and the psychologist. The physicist is generally content with analysis of a complex body into elementary ones. The psychologist more frequently observes that identical elements, *e.g.* the notes of a melody, may be differently combined to yield quite a different melody, and that the same melody may nevertheless be evoked from a set of quite different notes by transferring it into another key. But the psychologist goes beyond the conclusion that the properties of a whole depend on the *kind* of combination of the parts; he insists that in the living organism the parts are themselves altered by separation from the whole, and that within it they depend on interrelation between parts of the system to which they belong, and even more generally on the configuration of systems of wider and wider complexity. Thus *formal*, as well as *material*, bases of heredity must be (as, indeed, they are being) taken into consideration.

The controversy in regard to gradation as opposed to sudden changes in inherited characters may gain some help from the fact, well recognised in psychology, that

some sensations have an 'all-or-none' character—that is to say, if they are evoked at all, their intensity is independent of the strength of the stimulus—whereas other sensations are graded. One basis for such gradation appears to be the integration of pairs of antagonistic sensory apparatus in such a way that activity of the one involves simultaneously inhibition of the other, and that all grades of such duplex-balanced responses are possible according to the strength, &c., of the stimulus. This arrangement is also responsible for the phenomenon of contrast and adaptation.

Wherever there would otherwise occur incompatible, antagonistic mental processes, inhibition steps in and represses one of them. The appearance in consciousness of an idea depends largely on its congruity with the total mental attitude. Mental acts are generally set in a matrix of more persistent mental attitudes—'fields' of attention, &c., with which they are compatible. The revival of a forgotten idea may be impossible owing to the unfavourable 'constellation' which obtains at the moment. Such lack of incongruity between different systems, or between any given system and the whole of which it forms a part, is a notion employable in the problems of heredity.

During the development, and, indeed, throughout the life of the individual, well-marked changes may occur in its personality or in one or more of the mental qualities which go to compose it. Sometimes the character of the individual suddenly undergoes a complete change, as in cases of multiple personality. These phenomena, when considered from the standpoint of heredity, suggest that the individual actually inherits a vast number of mutually antagonistic characters, and that their actual appearance in the course of the life of the individual depends on what has been variously termed above internal configuration, constellation, and on such external influences as education and environment.

(See, further, p. 390.)

Tuesday, August 10.

22. Prof. JULIAN HUXLEY.—*Lecture on the Study of Growth and its bearings upon Morphology and Evolution.*

The study of the relative growth of parts of the body has many points of interest, both in itself and in its bearings on classification, evolution, and other subjects. The growth of most organs is roughly in direct linear proportion to the growth of the body as a whole. There are, however, many organs which grow disproportionately, or, to use Champy's term, heterogonically. Excellent examples of this are found in many crustacea, *e.g.* the abdomen in female shore-crabs (Carcinus), or the large chela in male fiddler-crabs (Uca). Analysis shows that these grow according to the formula $y=bx^k$, where y=organ weight, x=weight of rest of body, and b and k are constants. This might have been prophesied *a priori* as the simplest formula for heterogenic growth, as it merely implies that the ratio for the growth-rates of organ and body remains constant throughout life.

In the above cases both sexes are alike at the opening of post-larval existence, and the differential growth continues till death. As a result neither the female Carcinus nor the male Uca has any fixed morphological proportions, since the relative size of the abdomen, or chela, is a function of absolute body-size.

Similar facts are found in other crustacea, but the heterogeny may only start at sexual maturity (chela of ♂ Maia).

A further point is that even within the heterogenic organ growth is not uniform. In chelæ the tip is growing faster than the base, the base faster than the body. The excessive growth of the chelæ also induces slight overgrowth of neighbouring parts. The facts can be brought into relation with Child's physiological gradients.

In many insects similar relations are found for various organs, *e.g.* the mandibles of stag-beetles (*Lucanidæ*) and the 'horns' of dynastidæ. Here, since the organs only appear at the imaginal stage, we must postulate the formation at a heterogonic rate of some substance which determines the size of these organs.

A peculiarly interesting case is found in ants with polymorphic neuters. In some species all gradations are found, from small workers to large soldiers, and in these the head-weight bears the same relation to body-weight as does the chela of Uca, &c. This indicates that in all probability the different forms are not genetically different, but have merely had their larval development stopped at different absolute sizes.

Another interesting case of differential growth is afforded by the antlers of deer. In red deer, in spite of the fact that antlers are shed every year, the same average

relation is found to hold between body-weight and antler-weight as between body-weight and chela-weight in fiddler-crabs. From this and from the facts known with regard to the growth of imported Scotch deer in New Zealand, it can be confidently asserted that the differences in antler-size between the deer of various geographical areas are primarily due to environment, and not to genetic factors such as racial or sub-specific differences.

The same assertion can be made with regard to the so-called 'races' of certain insects. In Cyclommetus, a Lucanid beetle, five races or forms, each with a separate name, have been distinguished according to the type of the mandibles. Analysis shows that these are all parts of a continuous series; the different 'forms' are merely determined by the absolute size attained at perfection, and have no genetic or taxonomic significance.

With regard to embryology, it should be pointed out that many examples of recapitulation are direct consequences of differential growth of parts. In certain Brachiopods the half-grown and young stages represent the adult stages of an earlier and a much earlier form respectively; this can be shown to be due solely to the new type being produced by differential growth in certain regions of the shell.

Heterogenic growth may equally well be negative in sign, *i.e.* the organ may increase less rapidly than the rest of the body. This appears to be frequently the case with vestigial organs; in that case, wherever a vestigial organ recapitulates past history by starting of greater relative size than that which it finally reaches, the 'recapitulation' may equally well be put down to negative differential growth being the simplest biological method for producing an organ of small size. That changes due to differential growth need have no evolutionary significance is seen in the developments of the urinogenital systems of the two sexes in *e.g.* mammals from a common type, by means of positive heterogeny of some parts, negative heterogeny of others. If these changes were recapitulatory we ought to assert that the ancestral mammal was hermaphrodite, which is highly unlikely. Thus recapitulation of growth-stages may be only recapitulatory as an accident, the essential fact being the convenience of differential growth as a developmental mechanism.

The most interesting facts from the evolutionary point of view are afforded by the comparison of heterogonic organs in related species. Here, as G. W. Smith and Lameere have shown, the same general law still holds, the species of *absolutely* larger bulk having the organ of *relatively* greater size. This has been shown to hold for fiddler-crabs, for red deer, *i.e.* Wapiti, and for various insects.

This has an important bearing upon theories of orthogenesis. In *e.g.* the classical case of the Titanotheres, where, according to H. F. Osborn, several separate lines independently develop horns and show subsequent increase of horn size, we need no longer postulate independent change in the various lines of genetic factors controlling horn-growth. All we have to postulate is (1) the existence within the group of a developmental mechanism for heterogonic horn-growth similar to that shown to exist for deer antlers, (2) an increase of absolute size during geological time; this is probably a biological advantage, and not itself an orthogenetic change.

The other classical example of the Irish 'Elk' (*Cervus megaceros*) can be explained on similar lines: increase of absolute size automatically caused relative increase of antler-size to the limits of biological possibility.

The study of relative growth of parts thus may throw important light on morphology (absence of constant specific form or proportions); on taxonomy (invalidity of certain so-called forms or races, which are in reality only size-variations, due primarily to environment); on polymorphism (in ants, &c.); on embryology (recapitulation) and on evolution (with regard to orthogenesis).

23. **Joint Discussion** with Sections C (*q.v.*) and K on *The Concept of a Species.*

24. Dr. K. E. Carpenter.—*On the Toxicity of Lead-Salts to Fishes.*

Following upon the study of lead-pollution of rivers, a detailed investigation of the action of lead-salts on fishes has been undertaken in the laboratory. The preliminary study had shown that amazingly dilute solutions of lead-salts might have a fatal effect, and an elaborately standardised series of laboratory experiments has rendered it possible to demonstrate mathematically that, accepting Powers' laws of

velocity of fatality, there is *no theoretical limit* to the toxicity of lead in dilute solutions.

The velocity of fatality curve, though definite in outline, does not entirely conform to the normal standard for toxic substances; an interesting problem is suggested with regard to the definition of toxic action in general.

25. Mr. J. T. Cunningham.—*Experiments on Artificial Cryptorchidism, and Ligature of the Vas deferens on Spermatogenesis in Mammals.*

It has long been known that the undescended testis in the condition termed cryptorchidism is sterile. It was suggested by Dr. F. A. E. Crew that the reason of this was the higher temperature in the abdominal cavity than in the scrotum. The same suggestion was made by Mr. Carl R. Moore, of Chicago, who has published evidence in support of it. Mr. Cunningham described an experiment made by himself on a rabbit, showing that in a testis detached from the scrotum and placed in the abdomen the seminal tubules degenerated and the interstitial tissue was relatively greater in amount, while the testis of the side not operated upon remained normal.

Three other experiments on male rabbits described in the paper confirmed the results of Mr. Carl R. Moore and his American colleagues, showing that ligature of the vas deferens in the abdomen did not cause degeneration of the seminal tubules with apparent increase of interstitial tissue.

The paper supported the conclusion that the results attributed to ligature of the vas deferens were really caused by some alteration in the normal position of the testes in the scrotum.

Exhibits.

Mr. G. R. de Beer :—

1. Models illustrating Chondrocrania (Cartilaginous skulls of embryos).
2. Preparations showing the Development of the skeleton of the Fowl.
3. The Histology of the Pituitary body.

Mr. G. L. Purser.—Calamoïchthys (drawings, &c.).

Dr. Heslop Harrison.—Specimens showing inherited Melanism.

Mr. Tate Regan, F.R.S.—Fishes from Lake Nyasa.

Dr. Monica Taylor.—Amœba, &c.

The Exhibition included :—

I. Laboratory cultures of *Amœba protens*, microscopical preparations of the living animal and a series of preparations illustrating its life-history.

II. Micro-aquaria illustrating the technique of cultivating some animal types useful for biological teaching.

Amœba protens, the largest of the free-living amœbæ, though widely distributed, is difficult to obtain in large numbers, *to* time, at all seasons of the year. It is largely employed for all kinds of biological work and for teaching. Flourishing laboratory cultures are, therefore, a desideratum.

Frequent fission divisions characterise the adult amœba. True mitosis has not yet been observed in the nuclear divisions. The adult nucleus consists of a centrally placed karyosome connected by an achromatic network with the nuclear membrane, and lying in the nuclear sap. The chromatin occurs in several hundred small blocks lying under the nuclear membrane. A rudimentary form of mitosis occurs in the division of these blocks, which increase in number as the nucleus grows.

Its fission cycle being over, the amœba proceeds to form encysted young, a phenomenon which can frequently be detected by the pH of the water of the culture. This phenomenon is initiated by the escape of chromatin blocks (*cf.* chromidia) from the nucleus into the surrounding cytoplasm, where they set up activities in which the nutritive spheres of the mother amœba play an important part, the end-result being the formation of a large number of minute (5μ diameter) encysted young amœbæ.

The whole of the nucleus of the mother amœba is not used up in the process. The ectoplasm of the mother amœba forms a thin covering round the encysted young. When it disintegrates, these latter fall to the bottom of the aquarium. After a period of time, the young hatch out, and attain maturity in about six months.

Prof. L. P. W. Renouf.—Photos, &c., of Fauna of Lough Flyne.

Rev. Brade Birks.—British Chilopod and Diplopod Fauna.

For the purpose of this exhibit, the main subdivisions of the two classes are those given in the articles ' Centipede ' and ' Millipede ' by R. I. Pocock, F.R.S., *Encyclopædia Britannica*, 1910, Vol. V., pp. 669-674, and 1911, Vol. XVIII., pp. 468-475. Some bionomic, distributional, and diagnostic particulars are indicated.

Prof. E. B. Poulton.—Mimicry in the forms of ' Papilio dardanus.'

Dr. Pixell Goodrich.—Phagocytosis in Gammarus.

Dr. T. S. P. Strangeways and Dr. H. B. Fell.—Differentiation *in vitro.*

Dr. J. G. Thomson.—Fish Coccidia recently described as Intestinal Parasites in Man.

Dr. G. D. Hale Carpenter.—Specimens of Butterflies of the genus Pseudacræa and map of distribution.

Mr. Scott.—Photographs of eminent American and other Biologists.

SECTION E.—GEOGRAPHY.

(For references to the publication elsewhere of communications entered in the following list of Transactions, see page 446.)

Thursday, August 5.

1. Mr. H. O. Beckit.—*The Site and Growth of Oxford.*

Evidence of occupation by prehistoric man on or close to the present site of the city exists, but the rise to importance as a centre of settlement of what is now known as Oxford does not seem to be very ancient.

Topographically the site is determined by the occurrence, near the confluence of the rivers Thames and Cherwell, of patches of river gravel rising above the flat alluvial floors of valleys traversed in braided channels, and very inadequately drained, by these two streams. Only towards the north, along a staircase of these older valley deposits, now isolated as terraces, *i.e.* just where the largest extension of the modern town has occurred, is it possible to leave Oxford without crossing one or other of these belts of damp and periodically flooded bottom land. On three sides, therefore, the site is relatively defensible, but the building of roads—to east and west and south—is a matter of some difficulty ; even to-day made roads in the Oxford district run for the shortest possible distances on alluvial ground. Where practicable the older tracks avoid also the bare clays.

Passing to wider geographical relations, it is to be noted how Oxford lies in a critical, transitional position in the entrance to a gap in the scarpland of the Oxford Heights, which has to be climbed by all roads except those to the north and that branch of the western road which finds easy passage through the lateral Botley Gap. None of the roads now radiating from Oxford belongs originally to a planned system of general communication : all represent gradual improvements of local roads or trackways. Oxford lies off even the side-roads of the Roman period, and it is to be presumed was of no importance in Romano-British times.

It is possible, however, to trace the development of the city from Domesday Book and beyond, and to find in that growth some significant environmental influences, such as (1) the cramped area of the peninsular gravel terraces, beyond the limits of which the houses of the town have stretched only quite recently, and (2) a growing nodality discernible in increasing measure as first river navigation, and later on canal, metalled road, and rail, linked up larger and larger areas of the south-eastern English lowland about a notably convenient centre for communications. Oxford lies sufficiently removed from London to dominate the surrounding territory, like itself non-industrial. Favoured by position, and still more by its fame among the schools, it has grown from one of many Thames-side towns, mostly markets or road stations, into a city of nearly,

and with outlying suburbs considerably over, 60,000 inhabitants—a population which, outside London and south of a line joining the Bristol Channel and the Wash, is considerably surpassed by that of only nine other towns.

2. Sir George Fordham.—*Roads on English and French Maps at the end of the Seventeenth Century.*

This paper is presented as a comparative study of two large maps, showing particularly the roads of France and of England and Wales respectively, dated nearly contemporaneously towards the end of the seventeenth century, and drawn upon nearly the same scale.

The map of France is in manuscript, has, apparently, never been engraved, and is at present in the library of the Ministry of War in Paris. It measures 8 ft. 4½ in. in width by 7 ft. 3 in. in height, is drawn in bright colours, and is entitled '*Carte des Grandes Routes de Carrois du Royaume de France cottées suivant les distances itinéraires envoyées par Messieurs les Intendants.*' The royal roads are specially distinguished, with the distances between towns. It bears neither date nor name of author, but it seems safe to attribute it to the last quarter of the seventeenth century, and probably to a period between 1691 and 1696. The vessels drawn on the sea in this map indicate the same epoch, which also the general appearance and technique in drawing and detail would justify.

The second map, that of England and Wales, is engraved, and has a much more complicated history than that of the French map. It is in twenty sheets, and measures in the whole 5 ft. 7¾ in. in width by 4 ft. 5¾ in. in height. The original plates were published by Christopher Saxton, the first English cartographer, about the year 1584, or possibly a little later. The map is specifically referred to by Ortelius in his list of map-producers in the edition of his *Theatrum* of 1592, while it was not mentioned in the earlier list of 1584. It lay dormant for a century, apparently, until Philip Lea undertook the republication of all Saxton's county maps of 1574 to 1579 and of this general map also. The latter Lea largely altered in the ornamental marginal details—title, dedication, &c. &c.—and, after erasing most of the Elizabethan ships with which Saxton had decorated the seas, engraved in their place a series of vessels of his own period. He specially added the roads over the whole land-surface after the surveys of John Ogilby, which had been published in 1675. The title of this map as drawn by Saxton is not known, though traces of it can be discerned underlying Lea's elaborate design. This includes the new title, running: 'The Travellers Guide being the best Mapp of the Kingdom of England and Principalaty (*sic*) of Wales. Wherein are Delineated 3000 Towns and Villages more than in any Mapp yet Extent, besides ye Notations of Bridges and Rivers, &c. To which is added ye Direct and cross Roads according to Mr. Ogilby's late Survey, Described by C: Saxton. And now carefully Corrected with new Additions By Philip Lea.' Above the coat of the Royal Arms the initials of James II ('J.R.') justify the assumption that this map was republished by Lea during the brief reign of that monarch (1685-1688), and it probably appeared towards the end rather than earlier. The author, besides discussing these two maps —the earliest of any large size on which roads are laid down—and their characteristics, gives a slight historical sketch of the introduction of roads on maps from the beginning of the sixteenth, and particularly during the seventeenth, century, and refers to such maps as exist for that period in France and England and to the general history of the subject.

3. Presidential Address by the Hon. W. Ormsby Gore, M.P., on *The Economic Development of Africa and its Effect on the Native Population.* (See p. 113.)

4. Joint Discussion with Section H on *The Effect on African Native Races of Contact with European Civilisation.*

Speakers: Rev. Edwin Smith, Sir F. Lugard, Capt. G. Pitt-Rivers, Prof. J. W. Gregory, F.R.S., Hon. Hugh Wyndham.

Friday, August 6.

5. Dr. D. G. Hogarth, C.M.G.—*Our Near Eastern Borders.*

Since Great Britain has no territorial possessions in the Near East except the island of Cyprus, she, strictly speaking, has not 'borders' there that are worth considering. But through the southern half of this region passes a marine corridor which, as providing an essential passage between the Home Country and her Eastern Empire, must be more or less imperially controlled by her. Moreover, with a view to such control of its narrowest and most vulnerable pass, she has seen fit to impose military control on two regions, one on the Asiatic side, the other on the African side of it, which form one continuous geographical block of similar superficial character throughout. The corridor, therefore, may fairly be regarded as implying borders on this side of it and on that which are in great measure 'ours,' and these, being enlarged at one point of it, give us inland frontiers set well back into the body of the Southern Near East, and inevitably affected by its general effects of geographical conditions upon the society of the whole region.

Accordingly, these conditions are broadly considered at the outset, the most dynamic being those of superficial formation and of climate which, causing general aridity, render population over the larger part of the area nomadic and sparse, and even in the remaining part much subject to nomadic influences, and, further, by limiting agriculture and restricting free water, produce a general pastoral habit and its least favourable consequences. Also there fall to be considered the conditions of orographical structure, which largely forbid nowadays the existence of natural ports adapted to overseas shipping; though in antiquity there were several harbours adequate to the needs of the time. This defect has artificially been remedied in Northern Egypt with marked social results, which are contrasted with those produced in Asia Minor, Syria, and Arabia by a less favourable coastal history.

The particular conditions of the corridor borders are thus considered, and it is argued that the African shores of it call for more attention and control than the Asiatic, and that, in particular, the Arabian coast of the Red Sea is negligible. As for the two territorial enlargements of our border, the Palestinian and the Egyptian, it is shown that, while Palestine itself has very weak frontiers, the whole of it, regarded with Sinai as a border-belt to the corridor, constitutes a very strong flanking defence. So too, on the other side, for different geographical reasons, does Egypt, which is so barred from the rest of Africa as to be really an outlier of Asia. The conditions of access to it from the north and the influence which the Sudan can exert on it from the south are stated, and the necessity of any foreign controller of Egypt controlling also the Sudan is emphasised.

Finally, the geographical conditions affecting the Red Sea section of the corridor are considered, whether the coasts are under our control or that of others. Perim and Bab-el-Mandeb are taken to form the Gate of the Middle East, even as the pass between Crete and Ras-el-Tin is that of the Near East; between these points only lies the scope of this paper.

6. Dr. R. T. Gunther.—*Elizabethan Astrolabes and Theodolites.*

When the Lewis Evans Collection of historic scientific instruments was accepted by the University of Oxford it was foreseen that it would act as a loadstone and attract cognate objects. This expectation has now been realised in a most striking manner in the case of the series of astrolabes and theodolites. Valuable examples which were in danger of being destroyed have been saved, to the extension of our knowledge of the use of both of these important geographical instruments, and at the same time tardy justice can now be done to the consummate craftsmanship of their almost forgotten maker, Humphrey Cole, c. 1520–1591.

Cole's great 2-foot astrolabe of 1575, now exhibited to the British Association by the courtesy of the University of St. Andrews, shows us clearly for the first time that there was in London a scientific-instrument maker skilful enough to make and graduate large instruments of the class used by Tycho Brahe, and it was probably under construction when Cole was equipping Frobisher's first N.W. Passage expedition with navigational instruments. The finest known example of a seaman's astrolabe of rather later date by Elias Allen belongs to the same collection.

Another instrument by Cole, found in St. John's College, proves to be the earliest theodolite known. It was made within fifteen years of the date of the first published

description of this most important of English surveying instruments. Its relation to the Theodelitus of Digges, and to his Topographical Instrument, were discussed.

All these and other historic instruments were on exhibition with the Lewis Evans Collection throughout the meeting.

(Visits were arranged to the Lewis Evans Collection of Scientific Instruments in the Old Ashmolean Building.)

7. Mr. A. R. Hinks, C.B.E., F.R.S.—*Notes on the 'Pantometria' of Leonard Digges.*

8. Dr. Vaughan Cornish.—*Form and Pattern in Scenery.*

This is part of a comprehensive investigation of the Æsthetics of Scenery. Apparent Magnitude, Tone and Colour, and Rhythmic Motion (in part) have been dealt with in *The Geographical Journal* and *The Geographical Teacher*, and papers upon other pictorial categories are in preparation. In the present communication an account is given of determinations of the angle subtended by the field of effective view and of its relation to the apparent individuality of the component parts of a mountain range seen from different distances. Similar observations have been made on the apparent grouping of the stars in relation to the field of general view and of more distinct vision respectively, the former having a connection with certain large groups comprising more than one constellation, which have received little attention, and the latter with the small groups known as asterisms.

Afternoon.

Excursion to Brill.

Saturday, August 7.

Excursion to the Cotswolds.

Monday, August 9.

9. Mr. W. R. Dunlop.—*Queensland and Jamaica.*

In continuation of previous studies in other regions, an attempt was made in this paper to explain by analytical methods the exact reasons for the greater prosperity of Queensland as compared with Jamaica, both of which are tropical and contain approximately the same number of inhabitants (850,000 to 900,000). Queensland is over one hundred times larger in area and has far greater resources, and, since her inhabitants occupy on an average 445 acres per head compared with 3 acres per head in Jamaica, it follows that Queensland is fundamentally a Land Economy, whereas Jamaica is fundamentally a Labour Economy. But racial ability is a determining factor in prosperity.

Evidence of the difference in prosperity is shown by greater productivity per head (£68 per head per annum in Queensland and £8 6*s*. in Jamaica), larger foreign trade, more people paying income tax, higher real wages, and better housing in Queensland, but higher taxation because of the State's large public (external) debt, which is not oppressive.

The underlying physical reasons include Queensland's natural pastures and varied mineral and forest resources and supply of artesian water, and Jamaica's liability to natural disasters, especially hurricanes. The economic reasons include Queensland's greater borrowing power, less variation in exports, her development of manufacturing and of railways. But Jamaica gets more out of each unit of land occupied, the productivity being £3 6*s*. per acre, compared with 3*s*. 2*d*. per acre in the case of Queensland. Social reasons include better public health, more literacy, and much less crime in Queensland. Also the average mental age test (*i.e.* intelligence) is higher in Queensland.

The relative efficiency of production and public administration is discussed. It is concluded that Queensland's prosperity is due almost as much to her energy and ability as to her resources. But in spite of the Commonwealth she depends on foreign

trade. Her domestic politics are therefore dangerous. Jamaica is small and backward; she lacks industrial leadership; but prosperity could be increased by reform in education along psychological lines and the reorganisation of certain industries on the basis of expert economic investigation.

Included in the paper were graphs, tables, photographs and maps.

10. Mr. Michael C. Andrews.—*The British Isles in the Nautical Charts of the Fourteenth and Fifteenth Centuries.*

Although the southern coasts of England appear in the earliest known nautical chart, the mapping of the British Islands by the navigators of southern Europe was of later date than that of the Mediterranean Basin. While, owing to a lack of material, the origin and development of the Portolan Chart is still the subject of divergent theories, the evolution of this group can be traced, from its earliest rudimentary form, through several stages of expansion, in the work of the Italian and Catalan cartographers.

A comparative examination and classification of over one hundred examples, dating from the fourteenth and fifteenth centuries, demonstrate that the representation of the British Islands, during this period, may be assigned to four main types, each of which may be further subdivided into several varieties. It is therefore possible to gain an adequate and not inaccurate general view of the work of two centuries from the inspection of a limited number of typical examples.

Type I. *Genoese.*—(*a*) Early form, 1313–1321; (*b*) later form, 1327.
Type II. *Venetian.*—(*a*) Early form, 1373–1421; (*b*) later form, 1408–1446.
Type III. *Catalan.*—(*a*) Prototype, 1325–1339; (*b*) early form, 1375–1413; (*c*) revised form, 1426–1468; (*d*) standardised form, 1461–1584.
Type IV. *Late Fifteenth Century* (origin uncertain), 1462–1534.

11. Dr. R. C. Murphy.—*Marine Distributions on the West Coast of South America.*

12. Mr. H. O. Beckit.—*The Report of the Advisory Committee on the making of a Population Map of the British Isles.*

Afternoon.

Excursion to the Central Chilterns.

Tuesday, August 10.

13. Dr. G. D. Hale Carpenter.—*Travels among the Headwaters of the Nile (Uganda Lakes).*

14. Prof. H. L. Hawkins.—*The Goring Gap—an Introduction to some of the Physiographical Problems of the Thames Valley between Oxford and Reading.*

15. Prof. L. W. Lyde.—*Canada and the World Wheat Market.*

16. Miss G. H. Savory.—*The North-West Massif of France.*

The object of this paper is to demonstrate a method of subdividing such easily recognised geographical regions as the simple unit of the N.W. Massif of France.

While this region has definite unifying characteristics, both geological and geographical, its subdivision under the two headings is markedly different.

The dominant geographical control is the degree of facility in movement and transport. This control, though always important, has changed in relative importance.

The region, long a self-supporting one of backward development and restricted prosperity, has become a producing area of specialised high-priced perishables.

Hence a subdivision may be made in which ten zones are distinguished, the characteristics of each being determined by reference to means of communication with markets and sources of supply.

AFTERNOON.

Excursion to Goring Gap.

Wednesday, August 11.

17. Mrs. H. ORMSBY.—*Work on the Regional Survey of London at the London School of Economics.*

Voluntary regional survey work to be successful should be educational in itself and should lead to results of practical value. With these two ideas in view we have aimed, first, at the construction of base maps upon which information subsequently collected could be plotted, and which should show the essentials of the original geographical conditions of the area studied in so far as they could be determined: relief, natural drainage, surface geology, &c.

In an urban area this often involves much real research and is perhaps the most educative part of the work.

The base maps are laid down on a pre-arranged plan, so that all persons surveying sections of the same area should be working to the same scale, using the same selected contours, and employing the same symbols, methods of colouring, &c. This avoids waste of effort and makes co-operation in work and combination and correlation of results possible.

Upon the base map are plotted distribution of population at various periods, lines of communication, drainage, water-supply, distribution of occupations, &c.

Stereotyped methods in drawing up the base map do not preclude, but rather encourage, originality in further study.

18. Mr. W. FITZGERALD.—*The Regional Significance of Manchester—City and Port.*

The space relations of Manchester and its site are discussed, together with certain aspects of the historical geography of the region. Physical conditions have given to modern Manchester dominance as a centre, though other large communities less advantageously situated have grown up in the neighbourhood.

Lancashire retains certain advantages as the home of the cotton textile industry of Great Britain. Reference is made to the geographical position and function of Manchester in relation to the centres of South Lancashire. Manchester has developed as the organising and distributing centre of the industry. The peculiar organisation of the industry has resulted in heavy traffic through the heart of Manchester—Salford; this provides a real problem for the dual city. Though commercially dependent on Manchester, the cotton towns have maintained local independence in civic organisation. There is need for closer co-operation between the industrial centres and the regional capital where public services are concerned. While preserving local traditions and independence of outlook, it should be possible to establish the federal principle in S.E. Lancashire. The separate civic existence of Manchester and Salford represents an artificial division of an urban unit.

Liverpool gained importance as the cotton industry of the hinterland expanded. The system of communications between the port and the commercial capital of Lancashire did not satisfy the requirements of the latter. The function of the Ship Canal and its importance for Manchester are noted. There is a possibility of the transference of one of the functions of Liverpool to Manchester.

The character of the development within and around Greater Manchester involves discussion of the recent spread of population, changes in the method of utilising areas within the dual city, and the influence of the Canal upon land utilisation to the west of Manchester.

A regional planning scheme for the Manchester district exists; nowhere is the need for such a scheme greater. The aims of the local Town Planning Advisory Committee and certain recommendations from the 'Report upon the Regional Scheme' (1926), especially those relating to new transport routes and to a selection of areas for particular use, are outlined.

19. Discussion *on Regional Work in Geography.* Opened by Sir JOHN RUSSELL, F.R.S.

SECTION F.
ECONOMIC SCIENCE AND STATISTICS.

(For references to the publication elsewhere of communications entered in the following list of Transactions, see page 447.)

Thursday, August 5.

1. Presidential Address by Sir JOSIAH C. STAMP, G.B.E., upon *Inheritance as an Economic Factor.* (See p. 128.)

2. Sir R. HENRY REW, K.C.B.—*The Effects of Land Tenure Systems on Production.*

The factors of agricultural production may be classified under three headings: (1) Physical, (2) Economic, (3) Human. The physical factors are predominant; soil, climate, and situation determine the kind of crops, and largely the quantity produced. Economic factors may be summarised as cost and price. Human factors are the skill, knowledge, and experience of the cultivator. The influence of the tenure by which land is occupied is partly economic and partly psychological. Various systems of land tenure—absolute ownership, limited or conditional ownership, tenancy, share-tenancy, &c.—in different countries. The conditions on which the cultivator has the use of land react upon his enterprise and energy. The extent to which he feels secure in reaping the full advantage of his labour will affect the intensity of his effort and thereby the amount of produce obtained from the use of the land.

Friday, August 6.

3. Sir LYNDEN MACASSEY, K.B.E., K.C.—*Economic Aspects of the Labour Outlook.*

Effective collective bargaining is the basis of industrial stability. That depends upon the existence of representative and responsible employers' federations and trade unions. Recent events have shown the absence of this condition.

Present-day industrial requirements have altogether outstripped the current legislative principles and conceptions. They demand from employers' federations and trade unions a quickness of response beyond the power of their ponderous and slow-moving machinery. The kernel of the problem is reorganisation to constitute them as competent and fully responsible parties to industrial agreements concluded by them as any other person not under legal disability is in respect of his contract. This means providing for the validity and enforcement of collective agreements, which in this country, unlike most foreign countries, are by law unenforceable and therefore frequently repudiated.

If collective agreements are to be made enforceable, employers' federations and trade unions must have all the rights and be subject to all the obligations of ordinary contracting parties. This involves an end of sympathetic strikes and lock-outs in breach of agreement and the substitution of the legal remedy for the strike and lock-out argument of superior force. It also involves such a reconstitution as will ensure that the employers' federations and the trade unions properly ascertain and reflect the views of the majority of their members.

4. Prof. HENRY CLAY.—*The Authoritarian Element in Distribution.*

In the last century public opinion was opposed to any interference by authority with the distribution of wealth. Even if public opinion had favoured such interference, the practical difficulty would have presented itself of determining the principle or principles by which such interference should be guided; just as the absence of any general agreement as to what constitutes a fair wage has stood in the way of any regulation of wages by authority. Exceptions to the general rule were found in the grant of public relief, in taxation, and in such regulation of the form of wages as the

Truck Acts. In the present century these exceptions have extended so far and taken so many forms, that the actual distribution of wealth to-day is very largely determined by authority.

Prof. Bowley has examined the changes in the distribution of the national income between the years 1880 and 1913. The proportions in which the national income is distributed between different social classes and different categories of income show a remarkable constancy. In particular, average wages increased in the same ratio as average income. If intervening years are examined, however, it is seen that nearly the whole of the advance in real wages was made in the first half of the period in which the price-level was falling. The check to the rise in real wages since the end of the last century coincides with a marked increase in the interference of the State with wage settlements and with a marked increase in the distribution of the national income by authority through the media of taxation and public social services. If an estimate be made of the real income (as distinct from wages) of the wage-earner, it appears that this increased authoritarian element to a large extent compensated for the check to the rise in real wages, and that the economic welfare of the poorer classes has more than kept pace with the increase in national wealth.

Examination of the chief forms which this interference with distribution by the State has taken.

Discussion of the limits to which it can be carried.

Monday, August 9.

5. Joint Meeting and Discussion with Section M on *The Limits of Agricultural Expansion*, opened with

Presidential Address (Section M) by Sir DANIEL HALL, K.C.B., F.R.S., on *The Relation between Cultivated Area and Population.* (See p. 255.)

Speakers: Prof. D. H. MACGREGOR; Right Hon. LORD BLEDISLOE, K.B.E.; Sir THOMAS H. MIDDLETON, K.B.E.; Mr. R. J. THOMPSON, C.B.

Tuesday, August 10.

6. Prof. T. E. GREGORY.—*The First Year of the Gold Standard.*

The first part of the paper deals with the theoretical issues involved in the return to gold: the choice of the stabilisation ratio: the problem of internal as against external values and the use of wholesale as against cost-of-living figures. It is next pointed out that recent experience goes to show that the return to gold involves the danger of two different kinds of economic crisis: distinguished as 'Adjustment crisis' and 'Stabilisation crisis' respectively. The first year of the gold standard in England is taken as an illustration of the first, the position in Austria and Germany of the second type of crisis. In contrast, the developments in Holland and Sweden are examined.

The second part of the paper deals with the last eighteen months, and comprises a discussion of some general statistical aspects of the recent past, as well as an examination of the policy of certain trading central banks (Federal Reserve Bank, Bank of England, Reichsbank).

In the third part of the paper an examination is made of the course of events in the Latin countries and in Scandinavia.

The last part of the paper deals with the development of the theory of stabilisation and recent views on that topic.

7. Prof. W. GELESNOFF.—*The Russian Currency after the Monetary Reform of* 1924.

The Russian currency began to recover with the 'new economic policy' proclaimed in 1921. The economic situation at that time was unfavourable to elaboration of adequate provisional measures for the monetary reform. The reform was begun under adverse auspices (budgetary deficit and bad season). In fact, however, the difficulties proved not very hampering. A considerable increase in the quantity of

circulating money has not entailed its depreciation, owing mainly to two processes: (1) substitution of transactions on money basis for the barter, which reached considerable extent at the period of sinking paper money, and (2) the rise in the volume of trade as a result of general economic recovery. The currency could be increased with such reserves without any danger. The first reserve was, however, soon exhausted, because money basis for transactions was re-established already to the beginning of 1925, and as for the second, it gave until recently excellent results, even exceeding the anticipations, in consequence of the rapid recovery of agriculture and industry (the latter by using the fixed capital remaining idle from the period of military communism). The management of currency met, however, some difficulties owing to peculiar economic conditions of present Russia, where there are some regulated (staple industries, big trade) and some unregulated activities (agriculture, small industries, small trade). The movement of prices acquires under such conditions a peculiar character and fails to signalise the danger threatening the currency. It is possible that already in the autumn of 1924 the amount of money in circulation somewhat exceeded the limits allowed of by the increase in the volume of trade. A still greater lack of adjustment between the amount of money in circulation and the actual need thereof for the trade existed in the summer and autumn, 1925. However, the deficiencies in the money and credit policy did not very much affect the stability of currency, and usually they were being smoothed away for the next seasonal expansion of trade.

The peculiar feature of the monetary reform of 1924 is that it was carried into effect at the expense of the country's proper means, without any help from outside, and on the whole successfully.

It was accompanied by the general economic recovery and the improvement of State finances. It appears paradoxical enough that the first steps of monetary reform were easier than the subsequent ones. One of the important resources, contributing to the rapid progress in industry, viz. the part of fixed capital remaining idle, is now nearly exhausted. The insufficient accumulation of capital within U.S.S.R. and the lack of loans from abroad do not allow the industry to develop at the former rate. For the currency itself this presents no actual danger. But the economic life must change its tempo, and progress in a degree corresponding to the productive forces of this country is not to be expected until the time comes when the possibility of drawing capital from abroad presents itself.

Wednesday, August 11.

8. Mr. A. W. Flux, C.B.—*British Export Industries.*

'It is proposed to examine the changes in the overseas markets for the products of our leading export industries, more particularly with a view to measuring the changes in the character of the products taken by individual markets or by overseas markets as a whole.'

9. Dr. J. A. Bowie.—*Coal and Co-partnership.*

The economic peculiarities of the coal industry; the wide diversities between the units, in size, in method of capitalisation and in profit-earning capacity; the high labour cost and the relatively small capital required.

The relationship between the 1921 'profit-sharing' scheme and the recommendation of the recent Coal Commission; the claims and performance of the 1921 scheme in regard to employment, output, absenteeism and industrial relations; the problem of production in the coal industry on its human side, the effect of the difficulties of supervision, heavy labour turnover, bad time-keeping and the industrial aspirations of the miners.

The possible effects of a co-partnership scheme on output; the objections of labour; the dangers of making the scheme compulsory; a criticism of the methods suggested by the Labour Co-partnership Association; the attempts in France to introduce co-partnership in the coal industry; the essential conditions of success.

The details of a suggested scheme for the industry; the treatment of ancillary undertakings; the trade-union qualification for participation; the method of calculating divisible profits; the form of distribution; the question of workers' control in relation to co-partnership.

SECTION G.—ENGINEERING.

(For references to the publication elsewhere of communications entered in the following list of Transactions, see page 447.)

Thursday, August 5.

1. Dr. Ezer Griffiths, F.R.S., and Mr. Edgar A. Griffiths.—*Some Engineering Problems in Connection with the Refrigerated Transport of Apples.* Followed by **Discussion** on *Food Transport and Refrigeration.*

The paper is based on the observations made during the course of an experimental investigation of conditions in the holds of ships carrying apples from Australia to England.

In this branch of the overseas transport of fruit the ship has usually to serve the dual function of pre-cooler and carrier, as the apples are taken direct from the orchard to the ship.

In order to ascertain the variations of temperature from point to point in the cargoes cooled by representative systems of refrigeration, four ships were fitted out with resistance thermometers inserted in the fruit-cases. From the data obtained as to the temperature distributions, it was possible to suggest modifications so as to obtain (*a*) rapid initial cooling of the cargo, (*b*) uniformity of temperature throughout the mass. To cool down quickly, without freezing, a compactly stowed mass of fruit is a difficult engineering problem to solve.

Supplementary investigations have been made in the laboratory to determine the system of stowage which would result in uniform cooling of the cargo. True model scale tests could not be constructed, as this would necessitate handling 20,000 or more units representing the number of apple-boxes stowed in a hold. A novel scheme of vertical air-ducts is suggested and the design of dunnage required for this method of stowage is described.

The second problem considered is that of the ventilation of a ship's hold to remove the carbon dioxide produced by the respiration processes of the fruit.

The third problem is that of the design of instruments for use in connection with the transport of fruit. As the result of the experience gained on the voyage, modifications in temperature-measuring outfits now in use are suggested.

A robust form of resistance thermometer is described and the laboratory tests of same.

Various simple forms of carbon-dioxide measuring instruments are also described, and the limitations of various commercial forms of gas-analysis apparatus are indicated.

2. Prof. C. F. Jenkin, C.B.E.—*Small Refrigerating Plants.*

3. Mr. A. A. Rowse.—*Production of Motor Cars.* (Cinematograph.)

Friday, August 6.

4. Presidential Address by Sir John Snell, G.B.E., on *The Present and Future Development of Electricity Supply.* (See p. 156.)

5a. Mr. J. M. Kennedy.—*The Distribution of Electrical Energy.*

Until comparatively recently the generation of electricity for any district has been under the control of the local authority or company who have distributing powers in that district.

Technical developments of generating plant, coupled with legislation recently passed and now in contemplation, will bring about in the next few years a great concentration of generation in large stations, with the consequent closing-down of the smaller and less efficient stations.

Many undertakers will be able to purchase electricity in bulk at a considerably less cost than that at which they could generate for themselves, and will, therefore, concentrate their whole energies on the selling of electricity, which, after all, is their proper and legitimate sphere of activity.

Electricity in bulk (probably in the form of 3-phase alternating current at 11,000 volts and 50 periods) then becomes the raw material of these distributing agencies, whose function it will be to transform it into the form of energy required by their consumers and to distribute it throughout their area of supply.

The success or otherwise of a distribution undertaking may be judged by two main principles, as follows :—

(1) The difference between the average revenue and the average purchase-price per unit sold should be a minimum.

(2) The number of units sold per £ of capital invested should be a maximum for each class of distribution undertaking.

The paper deals with the problems involved in following these principles, which not only include the technical questions relating to transformation and distribution, but also the consideration of the most desirable forms of tariff for the bulk supply and for the different classes of consumers in any district.

An analysis is given of the various costs incidental to electrical distribution. The effect on load factor and revenue of a properly balanced rate system is pointed out, together with the cumulative increase in number of units sold per head of population resulting from each decrease in the price charged for the various classes of supply.

5b. Mr. Borlase Matthews.—*Electric Ploughing.*

6. Prof. Wm. Cramp.—*Some Phenomena of Electric Conduction.*

An electric current is generally held to be due to the *relative* motion of protons and electrons. Thus if $-e$ be the electronic charge, N the number of protons or of electrons per cubic cm., U the drift of the protons, and V the parallel drift of the electrons, then the current density is

$$-NeV+NeU=Ne\,(U-V).$$

This argument receives support from the work of Rowland, but his experiments are not conclusive. It is also in accord with the general facts of electrolysis. But there is no experimental proof of the assumption that a negative charge of given magnitude moving at a given speed produces the same magnetic effect as a similar positive charge moving at the same speed in the opposite direction. In metallic conduction it is generally supposed that the electrons only drift. In electrolytic conduction both anions and cations drift. The question arises, therefore, 'Is the magnetic field produced by an electrolytic conductor the same as that obtained when a metallic conductor of similar form carries the same current ?' Sheldon and Downing in 1898 attempted experiments to settle this question, and found no difference between the two cases ; but their method is open to much criticism. Physics text-books generally state that there is no difference, but they give no proofs. The author's plan was to compare the magnetic field produced by a tube of electrolyte carrying a given current with that produced by the same current when the tube was full of mercury. The electrolytes used were respectively silver nitrate and hydrochloric acid. Two methods of measurement were adopted for the magnetic field, viz. (1) the ballistic-galvanometer method, and (2) the direct-reading magnetometer. In all cases the magnetic field due to the silver nitrate was less than that due to the mercury, and that due to the hydrochloric acid was slightly less than that due to silver nitrate. Further, by both methods the percentage difference was very nearly the same, viz. just under 2 per cent. as between mercury and hydrochloric acid.

The possible causes of this difference have been examined. It is found that if the field were produced by electrons only the differences should be far greater. If it were due to the fact that in the electrolyte the drifting charges are loaded with drifting masses of matter, while in the mercury they are not, the differences should be much less. The results are not in harmony with the supposition that there is a difference between the magnetic field produced by a proton drift and that due to an electron drift. The author was finally driven to the conclusion that the difference is due to the fact that, in the metal, conduction is due to an electron drift of comparatively

high velocity. To prove this, experiments were made upon metallic conductors in which there was a sudden change of section. By measurements taken on reversal of the current a limiting value of electron velocity in metals was obtained and shown to be far higher than that of the ions in a solution. This, in the author's opinion, introduces phenomena at the cathode which hitherto have been neglected, but which are plainly visible in the case of silver nitrate. This is sufficient to explain the observed differences between the magnetic fields due to metallic and electrolytic conduction.

The conclusion is that the usual assumptions concerning the relationship between current and electron or proton movement are correct for metallic and for electrolytic conductors, but that, where a circuit contains both, the new electrode phenomena must be taken into account.

Monday, August 9.

7. Mr. H. E. Wimperis.—*The Rotating Wing in Aircraft.*

The employment in aircraft of a rotating wing has long had a fascination for inventors, but in spite of all their efforts very few machines fitted with rotating wings for sustentation have flown as much as a kilometre.

The requirement of safe descent with the power plant out of action is the most important requirement for such machines, but to the designer it has proved hitherto to be the most baffling.

It had for long been thought it must be quite impossible for any rotating-wing machine to rival the very slow speed of descent of a parachute having the same over-all diameter and carrying the same load. But actually the Cierva gyroplane tested at Farnborough in 1925 showed a degree of sustentation in vertical descent far in advance of this standard. A parachute carrying the same load and of the same diameter as the gyroplane would have descended twice as fast.

The mode of flight of a practical flying-machine like the gyroplane affords the best means of studying the performance of all types of rotating-wing machines. In this way it is practicable to proceed from the known to the unknown, rather than by an endeavour to proceed *ab initio* with an aircraft of entirely novel aerodynamic quality. The next step towards the unknown is to study the effect of applying a power drive to the windmill, at first when 'getting off,' and later when in flight. The issue may be a successful helicopter, or it may not; but in any case it is possible to cease exploration at the form of machine which gives the best combination of advantages, and at the worst there still remains a successful gyroplane.

The author makes use of Major Low's diagram to show how the speed of rotation of the wings is related to the load carried and to the landing speed.

An interesting feature brought out in this manner is that the process of climb and fall is continuous. There is no question of having to reverse the pitch of the blades or the direction of rotation. A reversal of rotation of the windmill is for reasons of safety obviously undesirable at any time; a change of pitch angle may on occasion, however, prove very useful—as when arising or alighting. But the construction shows that even with a constant pitch angle and a constant direction of rotation, steady and safe vertical motion is possible whether the windmill shaft is provided with a power drive or not.

The rotating-wing type of aircraft has certainly a future, but to what extent and in what fields it will prove to possess an advantage over the fixed-wing type remains yet to be determined.

8. Mr. D. R. Pye.—*High Duty Compression-Ignition Engines.*

Research was initiated in 1922 by the Air Ministry to explore the possibility of developing a compression-ignition engine burning heavy oil of a weight/power ratio possible for air work. In such an engine simplicity and lightness necessitate the direct injection of fuel without air compressors. Although the weight/power ratio is still prohibitive for air work, big advances have been made in regard to the output obtainable from a given size of cylinder with this type of engine. The present-day aircraft petrol engine weighs about 2 lb. per H.P. or less, and although the greater fuel economy of the compression-ignition engine will compensate, to some extent,

for greater actual engine-weight, a weight/power ratio of 3 must be aimed at. Compression-ignition engines built for other purposes give good economy, but only at low speeds and low m.e.p.'s, and consequently great weight per H.P.: for example, the lightest engine for submarine work weighs about 40 lb. per H.P. In order to keep down weight, it is necessary to limit the maximum cylinder pressure.

Research work has taken place along parallel but independent lines with 'jerk-pump' injection and with a mechanically operated fuel-valve. In single-cylinder work a B.M.E.P. of 115 lb. per square inch has been maintained, combined with good economy and low maximum pressure, up to a mean piston speed of 2,200 ft. p.m. This compares with a B.M.E.P. of about 70 lb. per square inch at 1,400 ft. p.m. in some commercial engines and with 130 lb. per square inch at about 2,300 ft. p.m. in aircraft petrol engines.

The chief problem is that of producing a fuel-jet which penetrates the compressed gas sufficiently to give adequate mixing of the fuel and air, and of obtaining at the same time sufficient pulverisation of the fuel to promote its vaporisation and combustion in the extremely short time available (about 3/1,000ths of a second at 1,200 r.p.m.). When working at the maximum cylinder output it has been found possible to burn 70 per cent. of the oxygen in the cylinder. Owing to the extreme difficulty of getting perfect mixing and so of burning all the available oxygen, and also to the nature of the combustion problem at high speeds, it is tolerably certain that the compression-ignition engine can never compete on level terms with the petrol engine as regards weight per H.P. Nevertheless, the potential benefit of eliminating all the complications and danger incidental to electric ignition and the possibility that better economy may compensate for extra engine-weight on a long flight, make the development of a compression-ignition aircraft engine an aim well worth striving for.

9. Dr. G. D. Bengough and Mr. H. Sutton.—*The Protection of Aluminium and its Alloys against Corrosion by Anodic Oxidation.*

A process has been developed for the protection of aluminium and its alloys against corrosion by means of a coating produced electrolytically. The article to be treated is made the anode in a suitable electrolyte, and its potential is gradually raised in a prescribed manner.

The effect of the treatment is to produce on the aluminium or alloy a thin, hard, and adherent coating of oxide or hydroxide of aluminium. The coating renders the metal much more resistant to corrosion in the atmosphere, in contact with sea-water and in other corrosive media; it affords a good base for greases, paints, or enamels which further increase resistance to corrosion; it can be coloured by dyes.

The process has proved to be capable of industrial application, and has already been operated on a considerable scale.

Tuesday, August 10.

10. Prof. F. C. Lea.—*The Effect of Superimposing a Torsional Stress on Repeated Bending Stresses.*

11. Mr. S. Timoshenko.—*Stress Concentration produced by Fillets and Holes.*

In many practical cases a very high stress concentration is produced by holes, grooves, notches, and sharp variation in cross-sections. This stress concentration is particularly undesirable where materials undergo reversal of stress. The majority of fractures in service can be attributed to progressive cracks starting from the regions of high stress concentration. In this paper it is shown that the elementary theory of bending of curved bars gives an approximate solution for the stress distribution in the case of a plate with a circular hole with bead reinforcement.

In the case of two-dimensional problems, the investigation of transparent models in polarised light gives the complete picture of stress distribution. Applying this method to the study of the stress at the root of gear-teeth, it is shown that with usual proportions the maximum stress is about 1.6 times higher than that as shown by the usual beam formula. This root stress increases with decrease in radius of the fillet at the tooth-root.

The effect of stress concentration in the case of reversal of stress was studied by using a fatigue-testing machine. By comparing the loads necessary to cause fracture under reversal of stress of (1) standard specimens and (2) specimens with fillets, the weakening effect of stress concentration can be obtained. This effect depends not only on the fillet proportions but also on the property of the material.

The experimental results contained in the copper show that the weakening effect of stress concentration in the case of ductile material can only be established accurately provided data on the fatigue tests of models of the particular machine-part are available.

12. Mr. EDGAR MORTON.—*Composition and Texture of Sandstones and Limestones in relation to Strength and Durability.*

Visit to Lewis Evans Collection of Surveying Instruments, Old Ashmolean Building.

13. Mr. EDWARD HUGHES.—*Influence of Voltage Harmonics on Power Factor Correction.*

Wednesday, August 11.

14. Prof. DAVID ELLIS.—*The Use of Sulphur Bacteria as Indicators in the Investigation of Polluted Water: The Blackening of the Sand in the Clyde Estuary.*

In the routine bacteriological examination of water for evidence of sewage pollution it is customary to make a count of the total number of bacteria per unit volume, and then to ascertain the number of such that may be ascribed to *Bacillus coli communis.* Such a procedure involves a fair knowledge of bacteriological technic, and takes time to accomplish. A clear water may or may not be polluted by sewage: its appearance is no guide to its bacteriological content. The writer has found the sulphur bacteria valuable agents in enabling him to detect sewage pollution in waters that superficially appear to be clean; and he has been better able in consequence of this aid to select samples of water for more detailed analysis. The sulphur bacteria are readily identified, and in most cases the organism of this group which is present in polluted waters is *Beggiatoa alba.* This microbe is described, and methods of identification, both microscopically and macroscopically, are given. It multiplies under circumstances where animal or vegetable remains are undergoing decomposition under water, or where a water, otherwise pure, has received sewage contamination. If it appears in a water, either flowing or still, in which organic remains are not undergoing decomposition, an almost certain sewage contamination is indicated. The presence of the organism may thus be used by the water engineer for the detection of such pollution, enabling him to select the best samples for more detailed analysis.

Application to a specific case.—The sand in the Clyde estuary at many parts is coloured black under the surface. It has been assumed, on superficial investigation, that the sewage poured into the Clyde was responsible. At various places in the Clyde area where the sand is blackened those points were noted in which *Beggiatoa alba* grew in abundance. Altogether some two dozen places of this kind came under observation. In every case where the organism appeared, the cause for its appearance could be traced either to animal or vegetable remains undergoing decomposition or to local sewage pollution unconnected with the hypothetically polluted matter in the main body of the river. In no single case was *Beggiatoa* found in the neighbourhood of the black sand in which both of the above factors were absent. It was thus possible to remove sewage-polluted water from the list of causative agents in the formation of black sand. As a result the way was clear for the ascertainment of the true reason, namely, the formation of ferrous sulphide produced by a chemical reaction between the ferruginous constituents in the sand and the hydrogen sulphide liberated by the bacteria which consume the animal and vegetable remains on the shore.

15. Prof. G. W. O. Howe.—*The B.E.S.A. Glossary of Terms used in Electrical Engineering: A Protest and a Suggestion.*

16. Mr. W. J. Kearton.—*The Distribution of Pressure in Impulse Steam Turbines at Varying Loads.*

The nozzle areas in impulse steam turbines are determined in the process of design so as to bring the ratio of blade velocity to steam velocity in each stage as near to that value which ensures maximum efficiency as economic conditions will permit. At partial loads in steam turbines of normal design, and also under the very variable conditions in turbines of the mixed-pressure and heat-extraction types, the nozzle areas are no longer correct and the distribution of pressure and hence of heat-drop in the various stages becomes very different from that which exists at the economical load.

The present paper outlines a method whereby the actual pressure distribution may be calculated. The pressure distribution in a nozzle is largely a function of the cross-sectional area at different points along the nozzle axis, and may be determined readily. In a turbine, however, the velocity of the steam is a discontinuous function. The method makes use of (*a*) a curve showing the actual total energy available by expansion from the initial to any given pressure, (*b*) a curve showing the approximate specific volume of the steam at any pressure, and (*c*) the equation of continuity. The calculation is by a step-by-step process beginning at the exhaust pressure.

The paper illustrates the application of the method to high-pressure steam turbines with nozzle-control governing in the first stage, to mixed-pressure turbines, and to heat-extraction turbines. The ratio of blade speed to steam speed is affected in certain stages to an appreciable extent, with a reduction in efficiency as a consequence. Relative steam velocities are altered and shock losses introduced. In certain types of plant, considerable free-expansion losses are involved.

17. Prof. C. H. Bulleid. *The Fatigue of Cast Iron.*

18. Dr. A. P. Thurston.—*Classification of Patent Specifications.*

Patent classification has to achieve various somewhat conflicting objects, *i.e.*: (*a*) to enable a manufacturer or individual to ascertain whether he may manufacture or use an article or process with impunity; (*b*) to enable a manufacturer or individual, in the event of receiving a threat of an infringement, to ascertain what his chances are if he fights the action; (*c*) to enable an inquirer to ascertain the whole existing public knowledge of any art or manufacture; (*d*) to enable an inventor or his agent to claim as much as possible under his patent; (*e*) to enable the staff of H.M. Patent Office to protect the public by seeing that no more is claimed than is permissible, *i.e.* that the claims are novel; (*f*) to enable a manufacturer or individual who finds that his competitors have obtained patents to demonstrate the invalidity of such hostile patents or to restrict their scope.

Patent classification should obey the basic laws of classification, *e.g.*: (*a*) it should proceed from wide headings to narrow headings, from terms of great extension and small intention to terms of small extension and great intention; (*b*) it should be adapted to admit interpolations; (*c*) the characteristics chosen for subdivision of any one class or sub-class must be consistent throughout that class or sub-class; (*d*) the headings must be mutually exclusive; (*e*) the terminology used must be consistent, the meaning of terms being invariable throughout.

Patent classification is a classification of subject-matter rather than of literary material, and the subject-matter is available generally in penny numbers. Therefore it is not necessary to follow another law of book classification, namely, to allot a book to the nearest heading of the classification that will wholly contain it. The American schedule obeys this rule, but the British schedule, in which every subdivision is self-contained and in which there are no 'superior' and 'inferior' headings, does not.

The system adopted by the British Patent Office is, in the author's opinion, a superb achievement. It has now been in daily operation for over twenty years, namely, from the 1st of January, 1905, and has enabled searches to be made with precision

and accuracy. In the existing British classification, every specification is indexed thoroughly for all matter of interest, whether claimed or not, and appears in the indexes under all relevant sub-headings (this is not the U.S.A. or German practice). Each class or sub-class is specifically defined by the headings appearing under it and the references from it to other classes. There are no 'see also' references. The published classification and allotment of cases under it is exactly that used by the examining staff. This is not so in the U.S.A. office, where repeat copies are placed in the official search files, that are met only by cross-references in the printed key. This is not so, also, in German practice. The British classification is based upon construction or structure and not upon application. Nevertheless, the classification bears marks of its evolution from a classification based upon industries or application.

An exhibition of working refrigerating plants suitable for small businesses and domestic purposes was on view in the Engineering Laboratories, Park Road, from August 4 to August 10.

Mr. Leonard Andrews demonstrated the hydraulic classification of fine materials at 12.30 and 2.30 each day of the meeting from August 5 to August 10, in the Engineering Laboratories, Park Road.

SECTION H.—ANTHROPOLOGY.

(For references to the publication elsewhere of communications entered in the following list of Transactions, see page 447.)

Thursday, August 5.

1. Capt. G. Pitt-Rivers.—*On Method, Approach, and Diagnostic Fallacies in dealing with the Problem of Depopulation in the Pacific.*

The cultural anthropologist is constantly inviting the collaboration of specialists in other departments of research. A united effort on the part of ethnographer, biologist, psychologist, and demographer is called for. It has been left to recent workers, notably, for instance, to workers like the late Dr. W. H. R. Rivers and Dr. B. Malinowski, to appreciate fully that, in the matter of life or death of a race, mental and cultural as well as physical adaptation must be considered. When two races meet there are three ways by which one may extinguish the other—directly by violence, indirectly by the gradual substitution, through differential birth- and survival-rates, of one population for another, and thirdly, when they mix freely, by selective elimination of less adaptable characters. Racial decline and decline of population are often confused. Cultural clash by one racial group with another does not always initiate decline, it may promote the opposite. The factors of elimination most frequently listed as alleged causes of decrease of Pacific races can be grouped under two mutually contradictory classes. There is no evidence of any general decline before the advent of Europeans into the Pacific. The true approach to solving the problem of depopulation lies in elucidating the problems of miscegenation in relation to variations in adaptability.

2. Miss W. Blackman.—*Beliefs and Ceremonies connected with Modern Egyptian Saints (Coptic and Moslem) and their Ancient Analogies.*

3. Miss D. A. E. Garrod.—*Excavation of a Mousterian Site and Discovery of a Human Skull at Devil's Tower, Gibraltar.*

Excavations carried out in a rock-shelter near Devil's Tower, Gibraltar, have brought to light five archæological levels (maximum thickness 8 metres), resting ou a raised beach at 8 metres above sea-level. Typical Mousterian implements, with associated fauna, were present in all the levels, and in the fourth from the surface were found the frontal and one parietal bone of a human skull embedded in a hard travertine.

The cranium is being removed from the matrix in the Department of Human Anatomy, Oxford, with the advice and assistance of Prof. Arthur Thomson.

4. L'Abbé Breuil.—*Lower Palæolithic Industries from the beginning of the Rissian to the beginning of the Wurmian Glaciation.*

5. Prof. Sir W. Boyd Dawkins, F.R.S.—*The Range of the* Anthropus Neanderthalensis *on the Pleistocene Continent.*

In dealing with the Neanderthal representative of existing man, it is convenient to mark his distinction from *Homo sapiens* by a different name—Anthropus—and to place him with the other members of the same indeterminate group under the name of Anthropidæ. These are, for the most part, so fragmentary that more evidence is needed before their place in classification can be clearly defined.

We now know, thanks to Fraipont, Boule, Sollas, and Keith, the physical characters of the Neanderthal hunter, and Elliot Smith has shown the important points in which the Neanderthal brain differs from that of *Homo sapiens*, and is akin to that of the higher apes. The Neanderthal hunter had not yet attained the erect posture, and though he had a brain larger than that of the apes, his mentality did not come up to the standard of modern man. His true place in classification is, therefore, not with Homo, but with the Anthropidæ.

The Neanderthal hunters ranged over a very large part of the Great Pleistocene Continent before the arrival of the Late Palæolithic tribes of the cave artists. Their skulls and bones have been found in the caves of Belgium, Middle and Southern France, and in the Mediterranean region in the caves of Gibraltar and Palestine. They occur in association with Early Palæolithic implements identical with those found in the river deposits over the whole of the intermediate areas. For these reasons the Neanderthal tribes may be taken to have been dominant in the Great Continent during the Middle Pleistocene Period, and before the arrival of the Artist Hunters, the earliest representatives of *Homo sapiens*—the Human Race.

6. Joint Discussion with Section E (*q.v.*) on *The Effect on African Native Races of Contact with European Civilisation.*

Friday, August 6.

7. Sir Arthur Evans, F.R.S.—*The Shaft-graves of Mycenæ and their Contents in relation to the Beehive Tombs.*

8. Mr. A. M. Woodward.—*Excavations at Sparta by the British School at Athens* (1924-26).

During its previous excavations at Sparta (1906-10), the British School had fully explored the Sanctuary of Artemis Orthia, and that of Athena Chalkioikos on the Acropolis (within the Sanctuary-walls only), besides tracing the Hellenistic City-walls. Work was resumed in 1924 with the object of exploring the Theatre and of more fully investigating the Acropolis behind it.

At the Theatre, already known as one of the largest in Greece, very little of the upper seats was preserved, but portions of the front rows were found undisturbed. The *cavea* seems definitely to date from the reign of Augustus. The retaining-walls had a facing of massive marble blocks along the *Parodoi*, and those of the *E. Parodos* were extensively inscribed with lists of Spartan magistrates, and their *Cursus Honorum* (*ca.* A.D. 100-150). Near its E. end a monumental exterior staircase led up to the *diazoma*.

No certain traces of the Greek stage remained, and the stage-buildings underwent much reconstruction under the Empire. Coins and inscriptions show the Theatre as in use (intermittently) nearly to A.D. 400. Then, after a period of abandonment, came a Byzantine settlement (ninth to thirteenth century). The Acropolis yielded

a rich series of votive objects, many inscribed with the name of Athena, representing debris from her Sanctuary. The pottery, which ranged from Geometric to Hellenistic and included some fine decorated Laconian ware, many fine archaic and later terra-cottas and bronzes, and, above all, a marble statue (*ca.* 470 B.C.) of a helmeted warrior (perhaps a portrait of Leonidas, or Pausanias ?), call for special mention.

9. Mr. W. A. Heurtley.—*Iron Age Pottery from the Vardar Valley, Macedonia.*

The pottery discussed in this paper comes from two mounds, Várdino and Vardaróftsa, both on the east bank of the Vardar, near Salonica. The stratum in which the pottery occurs lies in both cases immediately above a stratum of the Sub-Mycenæan age, and immediately below a stratum of the fourth century B.C. Thus, though there is overlapping, the limits of the Iron Age stratum can be fixed within half a century. They are 1050 B.C. and 400 B.C. Within those limits the pottery is practically homogeneous, and shows few traces of development or change. The types are few, and derive mostly from those of the preceding stratum, which covered the Late-Mycenæan period and part of the Sub-Mycenæan. An invasion, however, apparently from Central Europe, towards the end of that period introduced a class of black 'fluted' pottery into Macedonia, which left its traces in the Iron Age pottery. It seems probable that these invaders passed on southwards, and their influence appears in the 'Early Geometric' culture of Thessaly. The Iron Age pottery of Macedonia is a parallel development to that of Thessaly, and arose after the departure of the invaders.

10. Mr. R. Campbell Thompson.—*The Science of the Assyrians in the Seventh Century B.C.*

The readiness of the Assyrian and Babylonian doctors to tabulate everything in long lists is a good indication of their capacity for scientific observation. Their tablets of lists of animals, plants, and stones vouch for their great interest in natural history; they had a knowledge of some 250 plant-drugs, which reappear in their medical receipts, and of several chemical products, which are again found in their manuals for glass-making of the seventh century. They knew several formulæ for making and colouring different kinds of glass, and it would appear that they had anticipated the Purple of Cassius, and had even a method of making Aventurine. In mathematics they were expert at an early period in settling problems of the areas of fields, and about 2220 B.C. they were able to provide a fairly good formula for solving the length of the diagonal of a rectangle, when the length of the sides was given. In astronomy their desire to read the heavenly portents had made them very careful observers, and their tablets on this subject date almost down to the Christian Era. They knew at an early period the difference between the solar and lunar year, had divided the Zodiac into twelve divisions, and even in the seventh century were attempting to foretell lunar eclipses.

11. Mr. L. H. Dudley-Buxton.—*Anthropological Work in Mesopotamia,* 1925–26. (With exhibit in the Department of Human Anatomy, University Museum.)

Skulls and long bones in sufficiently good preservation to be of value were excavated in both Sumerian and Neo-Babylonian strata. No graves were found in the area which contained the early painted ware. A later cemetery was discovered near the southern end of the Kish mounds, but as it appeared to be of little archæological interest the chances of obtaining anthropological material had to be abandoned. A long series of measurements was made on the modern population. They appear to be of essentially the same type as their predecessors in the same area 5,000 years ago.

12. Prof. S. Langdon.—*Excavations at Kish.* (With exhibit in the University Museum.)

The discoveries of the Oxford and Field Museum Expedition in the season 1925-6 are confined to two periods, the Early Sumerian and Late Babylonian. Only the former

was discussed. At Kish the existence of painted pottery as late as 3000 B.C. is proven by the recovery of a fragmentary vessel with palm-leaf designs in black paint on a natural clay base. Fine stone bowls and copper objects were recovered from graves beside the great stage tower of Harsagkalama. At Jemdet Nasr the Expedition recovered a mass of the earliest-known monochrome and polychrome painted ware in Sumer, pictographic tablets, seals, and copper objects. The following conclusions was drawn from the discoveries.

1. Sumerian civilisation was older than Elamitic, and no influence can be traced to Syria and Cappadocia, whose pottery and glyptic appear 2,000 years later.

2. Borrowing and cultural influence are principles employed far too much in the study of ancient history.

3. Sumer and Egypt are the only possible claimants to precedence in the origin of civilisation.

4. In Sumer, Elam, and Egypt, the period of the best art came at the beginning.

13. Mr. C. Leonard Woolley.—*Excavations at Ur of the Chaldees, 1925–26.*

On a prominent mound in the south corner of the Sacred Temenos we found a building of Dungi, about 2400 B.C., attested by the copper figures and inscribed stone tablets found in its foundations. This seems to have been a temple. Cut into the ruins of this building were many tombs, brick-built, corbel-vaulted tombs or plain clay coffins, which yielded a rich store of pottery and other grave-furniture. We dug down 36 feet below the floors of buildings put up in 2100 B.C., finding a succession of stratified constructions of unknown date, the earliest yet discovered at Ur, but still in a metal-using age and not yet down to the level to which belongs the painted pottery of Al Ubaid. A number of vertical drains, made of terra-cotta pipes, riddled the soil. Of the same sort as the drains commonly employed for domestic sanitation, here apparently they were the channels down which were poured libations to the nether gods—a cheap form of the ' apsu ' made by kings in honour of Ea.

The main site excavated lay to the north-west. In the upper levels below the floors of a building dating from about 650 B.C., a quantity of the mud figures of Papsugal and other minor deities were found, which served as protective amulets for the house. Below this we discovered two magnificent copper coffins containing the bones of women, with their jewellery, work-baskets, copper bowls, etc. The lowest building of the site was a large temple of the goddess Nin-Gal, built originally by Bur-Sin (*c.* 2350 B.C.) and rebuilt a hundred and fifty years later by a certain Enanatum, son of the King of Isin and High Priest of the god Nannar at Ur. The building was a fortified square measuring some 250 feet each way. It comprised two distinct temples of the goddess, a shrine to Bur-Sin, the deified founder, and a dwelling for the priest. It was sacked and overthrown probably as the result of a rebellion of the city against the Babylonians in the twelfth year of Samsu-iluna, the son of Hammurabi. In the ruins we found a quantity of the votive objects from the sanctuary broken and flung away by the troops. The peculiar interest of the temple lay in the good preservation of its internal fittings, and in the extraordinarily modern kitchen attached to it, where the well, the ovens, and the cooking-range were still in serviceable state. As regards objects, we have a complete diorite statue of the goddess Bau, a marble head of Nin-Gal with inlaid eyes, a masterpiece of Third Dynasty art, another fine diorite head, an intact limestone plaque with two scenes of sacrifice in relief, the oldest example of sculpture yet found on the site, an alabaster disk with a scene of sacrifice in which the principal part is played by the daughter of Sargon the Great of Akkad, fragments of a historical stela of Hammurabi, two gypsum rams from the throne of a statue dating to before 3000 B.C., and a vast mass of other monuments of art and history.

Saturday, August 7.

14. Miss Violet Alford.—*The Ritual Dances.* (With illustrations by Members of the English Folk-Dance Society.)

(*a*) *The Invocation Dance.*

An exceedingly primitive type, used as a magical rite to call within range the desired animal food—the animal probably being the god as well as the food of the tribe which invokes it.

Examples still extant.

1. The Abbots Bromley Horn Dance.

2. Bean Setting (much later in spirit, by magical imitation of the sowing of the seed the dancers invoke or prepare a good harvest).

3. Shepherd's Hey (still less primitive, yet clearly showing the action of invocation).

In other countries, Mutil Dantza, Danse de la Pelle, Danse de l'Ours } Basque.

(*b*) *Processional Lustrations.*

Used for a twofold purpose—to purify the village of winter and want; to bring in summer, health, and wealth. *Cf.* Rogation Processions, the primitive ritual now directed by the Church.

Examples still extant.

1. Helston Furry Dance.
2. Castleton Garland Dance.
3. Tideswell Processional Morris.

   In other countries: Danse des Volants, Basque; Farandole, Provence.
4. Examples of English Morris with Processional to gain new dancing place.

(*c*) *Sacrificial Dances.*

The ritual dance now used for a very different purpose—the purpose of much later and more sophisticated minds. The god is now conceived as anthropomorphic, and, like a man, must be humoured and propitiated. Therefore, men gave him of their best—the village Chief.

Dances still extant showing sacrifice.

1. Kirby Malzeard Sword Dance, in which captain is killed.
2. Selections from other North of England Sword Dances.
3. Winlaton Sword Dance—showing the lock of swords as a symbol of the forgotten decapitation.

Examples in other countries: Czech Sword Dances. Basque Sword Dances, Viscaya and Guipúzcoa. Pueblo de Guzman.

(*d*) *Maypole Dances.*

The Maypole a symbol of the god of spring or vegetation.

Hardly any examples extant.

1. Gathering Peascods.
2. Sellenger's Round.

Monday, August 9.

15. **Presidential Address** by Prof. H. J. Fleure on *The Regional Balance of Racial Evolution.* (See p. 181.)

16. Dr. R. T. Gunther.—*The Hairlessness of Man.*

The acceptance of any theory as to the Descent of Man from lower mammals involves the acceptance of the view that his ancestors were fully clothed with hair. Whether for retaining the heat of the body, as a shaggy defence against blows or excessive solar radiation, hair is of such obvious utility to its possessor, and is a feature that is so persistently retained by heredity, that we are confronted with unusual difficulties when we try to account for its widespread reduction and loss. Clearly there must have been some general cause, yet no explanation hitherto given has been generally approved. Even Darwin felt that sexual selection was not wholly adequate.

The theory now put forward is one primarily of Natural Selection. We suggest that there was a time when hairy man was a positive danger to himself, and at a disadvantage as compared with the hairless man; also that hairlessness, whether accidentally or artificially acquired, became the outward and visible sign of the attainment of a certain standard of intellectual development. The special conditions which would render a thick hairy coat a peril were present when man had begun to play with fire without having learnt how to exercise caution in its use. A

singeing was the fashion would have had an advantage, which would in the course of time have been followed by congenital hairlessness improved by natural selection and fixed by sexual selection. Man was the unconscious controller of his own destiny. Two stages may be suggested. First, *Homo ignifer*; depending on natural sources for his fire and chance of cooked food, he played with fire, singed himself, and burned his hairy contemporaries. Secondly, *Homo ignigenius*; able to make fire for himself and to put it to good service, he learnt his lesson at the cost of his natural coat. Shakespeare was not far wrong when he wrote that what Time hath scanted man in hair he hath given him in wit.

17. Miss M. E. B. Russell.—*The Correlation between the Distribution of Human Hair-form and Geographical Regions.*

In order to provide an unprejudiced basis for testing such a possible correlation, the distribution of human types suggested by Dr. Haddon in his book, 'The Races of Man,' was adopted; the geographical regions of Unstead and Taylor were also accepted as representing a standard view of the various types of environment to which man is subjected. A contingency table was then made, the rows representing the regions and the columns the different races and sub-races of man. The contingency table shows that there is undoubtedly a high correlation between the two factors, with the exception of deserts, where the distribution is that of chance.

18. Dr. J. H. Shaxby.—*A Method for Estimating the Reflection of Light by the Skin.*

19. Miss R. M. Fleming.—*Anthropological Studies of Children.*

Consecutive observations have been taken on groups of school-children for several years. These reveal decided differences in the development of head-form and colouring between boys and girls, and also between children of different race-types. In addition, observations have been taken for the last two years on children of mixed origin in our seaport towns, though in the latter case there has not yet been opportunity to study prolonged growth. The essential feature of the work has been the following of individuals year after year, and the records are kept for each individual.

20. Mr. E. G. Bowen.—*Anthropological Types and Tuberculosis.*

21. Joint Discussion with Sections D and J on *Heredity in its Physical and Mental Aspects.* Opened by Dr. C. S. Myers. (See p. 366.)

Dr. R. N. Salaman.—*The Inheritance of Facial Types.*

The characteristics which go to build up the facial features and to mould the expression are infinitely elusive and impossible of definition. It is on these combinations of minute differences in respect to eye, nose, or mouth, that in life we base our judgment, our friendships, and not seldom our loves. Such infinitely fine variations defy Mendelian analysis.

Study of Jewish facial types has shown that, overriding these subtle differences is a very simple determining factor, viz. that of the roundedness *versus* the angularity of all the features of the face. Within the Jewish community roundedness is dominant to a specific type of facial angularity, and segregation is complete. Mating of round-featured Jews with persons of angular type but of Nordic blood, however, produces offspring in which the angular type is dominant, and here again segregation takes place. The observations show not only that the plastic features of the face are basically controlled by simple Mendelian factors, but that in the human race there are closely similar phenotypes which are genotypically distinct. This latter fact is of importance from the point of view of race determination.

That some relation exists between facial feature and psychological character is undoubted, and in the recognition of the rounded and angular types of face may be found a basis for the determination of such correlation. Such observations as have been made suggest that the possibility of a linkage between the rounded and angular types of facial feature with distinct psychological characteristics is highly probable.

Mr. THURKILL COOKE.—*Heredity and the Inheritance of Titles of Honour.*

Natural distinction and a sound heritage are essential to the concept of a heritable title of honour. How far, then, are noble characters hereditary ? Is their transmission fostered, or impaired, by the institution of hereditary dignities ?

Observations obtained from the study of pedigrees and other illustrative data show the trend of natural inheritance. Family distinction of a stable order is a product of slow growth. It is seldom won by sudden elevation, which brings a loss of adaptive equilibrium, and frequent reversion to the common ancestral level. Families which show a preponderance of noble endowments emerge, with greater chances of survival, from socially homogeneous stocks. Differentiations of type occur, displaying an intimate correlation of some physical with psychical characters. In the process the part played by the social environment and tradition is fundamental.

The confines within which the peerage fulfils its biologic function as a conservator of hereditary honour may be approached by statistical inquiry. We have evidence that in the operation of the system consequences detrimental to heredity ensue. Such effects in general arise from the admission to its ranks of elements which do not accord with its natural rationale, and from forced intermarriage with inferior stocks, which heralds the decadence or extinction of rich ancestral strains.

Tuesday, August 10.

22. Miss N. F. LAYARD.—*A Provincial Magdalenian Flint Industry from the Colne Valley, Essex.*

The finely worked flint implements which I am exhibiting to-day are the result of two and a-half years' investigation of a gravel-pit in the Colne Valley, Essex. Some were collected from the workmen in the ordinary course of screening the finer gravels, and others during excavations, in which I am still engaged, for establishing the conditions under which they are found. The implements occur at depths varying from 1½ to 3 ft., according to the accumulation of humus above, except where they are found in hoards on the floors of pit-dwellings, the depth of which may be from 4 to 6 ft. below the surface. Sections of the gravel-pit reveal these floors cutting through the stratified stony loam. Small hearths measuring 2 to 3 ft. across are also seen, not on the hut floors, but hollowed out of the original surface. The majority of the implements, though diminutive in comparison with those of preceding industries, are not minute enough to be described as pygmy, neither are they, except in rare cases, geometric in form. Thus they are distinguished from the Azilio-Tardenoisean cultures. Among thousands of fine flakes carefully fashioned for use, but lacking secondary finish, delicate points closely corresponding to the gravette form *à dos abattu* are found in considerable numbers. Saws, scrapers, points, &c., seem to suggest flint tools made for the purpose of fashioning wooden or bone implements. Thus they might be distinguished as 'implement-making implements.' Burins of several varieties have also come to light. It is rare to find any bone artefacts preserved on unprotected sites, but a highly polished bone *lissoir*, probably a needle-polisher, and a circular pierced bone pendant are perhaps the most interesting objects yet found on the site.

23. Miss N. F. LAYARD.—*Excavations on the Neolithic Workshops of Ste Gertrude, Holland.*

In 1924, by kind permission of M. le Comte de Geloes, I made excavations on the rich Neolithic site of Sainte-Gertrude, Holland. The object was to secure examples of the implements found in such large quantities in these prehistoric workshops for comparison with the artefacts of Neolithic man at Grime's Graves, Norfolk, and other similar English settlements.

Our work was rewarded by the finding of a profusion of flint implements—stone picks, axes, side-scrapers, wedges, and a variety of tools all suitable to the needs of a miner. In one of these *ateliers* measuring 15 ft. by 15 ft. no less than seventy stone picks were thrown out. This will give some idea of the abundance of material to be had for the seeking.

Tools corresponding in form to some of the more carefully worked specimens from Sainte-Gertrude have been found by me on fields closely adjoining Grime's Graves. These parallels I have brought for exhibition.

To Marcel de Puydt belongs the credit of the discovery of the Sainte-Gertrude site in 1881, since which time other distinguished savants have continued the work of investigation.

24. Mr. A. Leslie Armstrong.—*Excavations in the Pin Hole Cave, Creswell Crags.*

A systematic archæological exploration of this cave was commenced in November 1924, upon ascertaining that the work there of the Rev. J. Magins Mello, in 1874, had been abandoned 23 ft. from the entrance. Excavations have now proceeded 12 yards beyond Mello's terminal point, and to an average depth of 12 ft. down to bed-rock. Two layers of cave-earth are present, the uppermost sealed by stalagmite or breccia and unbroken except in small limited areas, where disturbance has taken place to a depth not exceeding 18 in. The fauna is a rich one, and Pleistocene in character. Human artifacts occur throughout the upper cave-earth of Aurignacian and Proto-Solutrian facies, including flint implements, amulets, bone tools, and an engraved lance-point of mammoth ivory.

Quartzite implements, considered to be Upper Mousterian, are found at the base of the upper cave-earth. The lower cave-earth contains Lower Mousterian implements, and, near the centre of the deposit, artifacts resembling Acheulian types, together with tools of bone and mammoth tusk. Lance-points of reindeer antler from the old Mousterian level are believed to be of a form new to science and ancestral to the single-bevel lance-point. The physical character of the lower cave-earth points to its accumulation having been completed before the floor of the Creswell ravine was cut down to its present level, and the contained artifacts provide valuable evidence for defining the period during which this lowering of the valley took place, which may have an important bearing upon the geological history of the Derbyshire and S. Yorks valleys in general.

25. Mr. V. Gordon Childe.—*The Terramare and the Hungarian Bronze Age.*

The traditional arguments for the derivation of the *terramaricoli* (Italici) from the Middle Danube valley need revision owing to the great uncertainty attaching to the existence of *terramare* in Hungary, the paucity of the specialised Hungarian types represented in Italy, and the lateness of the Hungarian Bronze Age. The latter period, to which belong the urn-fields, the *ansa lunata* vases and the *Buckelkeramik* with North Italian analogues, in fact begins only at the time of the maximum expansion of Mycenæan civilisation, and is parallel to the Italian *terramare* and the succeeding Pianello-Tolfa phase; *i.e.* the Hungarian Bronze culture is parallel and akin to that of the *terramare* but not its ancestor. Some of the points in common to the two groups, *e.g.* the crescent handle and the rite of cremation, can in Hungary be traced back to the 'late Neolithic' makers of corded ware who appeared also in Austria and constituted a dominant element in the Tumulus Bronze Age population of Bavaria. The ancestor of the *terramaricoli* may be assumed to be a mixture between corded-ware makers and lake-dwellers from the Eastern Alps, like the population of Bavaria and Western Hungary. That would accord well with the view that the Bavarian barrow-builders were proto-Kelts, while the Bronze Age inhabitants of Western Hungary may have been proto-Umbrians, since they used a prototype of the Villanova ossuary.

26. Miss M. A. Murray.—*Excavations at Stevenage.*

27. Prof. Sir W. Boyd Dawkins, F.R.S.—*The Cult of the Neolithic Axe.*

The stone axe used in ceremony by the natives in the Pacific Islands is held in regard because it had a place in their religion when they were in the Neolithic stage of culture, and the superstitions and mystical powers attached to Neolithic axes among both civilised and uncivilised races have their origin in a time when the stone axe was used in a Neolithic cult, just as the axe of bronze in the ritual of the Minoans, and possibly also of the early Greek worshippers of Zeus.

It is probable that the cult of the stone axe was carried on after the Neolithic Age into that of Bronze, and possibly into the prehistoric Iron Age.

The polished stone axe engraved on dolmens in Brittany probably belong to this cult, and the highly polished stone axes in the burial mounds of France, Germany, and Britain were probably made for the cult and were not intended for use. They are all of the French type, with the small end tapering to a point, and are singularly perfect. The occurrence of one of these in a burial mound near Stonehenge makes it likely that it was used in the cult of that ancient temple.

28. Prof. Sir Flinders Petrie, F.R.S.—*Egypt and the Caucasus.*

A recent suggestion that some names in the Caucasus region were like those in the mythology of the Egyptians seemed to have support from the probability of a northern origin of the Badarian civilisation. To test this all the place-names in the Book of the Dead were extracted, with their indications of position. Most of these names are found in the Caucasus in their relative positions, and the physical nature of the region agrees to the descriptions. The importance of any such connection makes full discussion desirable.

29. Miss E. W. Gardner.—*The Recent Geology of the Northern Fayum Desert.*

The country north of the Birket Qerun is now desert, consisting topographically of two plateaus, an eastern and a western, separated by a low-lying area running north for five miles from the lake towards the high cliffs forming the northern boundary of the Fayum.

Detailed examination has shown that the lake-beds of the plateaus, originally described by Beadnell and regarded by him as belonging to the prehistoric ancestor of Lake Moeris, must be divided into at least two series. Those which occur up to 222 ft. above the Birket Qerun belong to an earlier lake, which was certainly connected with the Nile at one time, as is shown by the fauna. Subsequently the connection seems to have been broken, the lake dried up, and the deposits were consolidated and greatly eroded.

At some later date a second lake came into existence, but only reached a maximum of 205 ft. above the present lake.

From that time all the evidence points to a fall of the water-level, probably in stages, down to the modern Birket Qerun—148 ft. below sea-level.

30. Miss G. Caton-Thompson.—*The Neolithic Culture of the Northern Fayum Desert.*

During the past two seasons work has been carried on in this region to determine the cultural status and relative date of the makers of the fine pressure-flaked flint-work hitherto known only from surface collections.

This industry appeared to be foreign to the Nile Valley, until recent finds in the oldest stratum at Badari, Upper Egypt, furnished a possible connection.

Evidence has been provided by systematic excavation of habitation mounds lying some miles north of the present Birket Qerun ; objects denoting the domestic, agricultural, hunting, and fishing activities of the period have been obtained from these, and the culture is shown to be of an advanced Neolithic type. The sites fringe the shores of the second lake period, and rest upon sands and clays deposited by the old high-level lake ; they show no sign of a subsequent submergence in historic times.

The topography of the ground and the distribution of high-level gravels emphasise the long period which elapsed between Middle Palæolithic times and the arrival of the Fayum flint-workers.

Wednesday, August 11.

31. Mrs. Zelia Nuttall.—*Fresh Light on the Ancient Calendar Systems of America.*

32. Miss Simpson.—*Wychwood Village Sites.*

The area to be described includes part of the Jurassic escarpment, which crosses England from S.W. to N.E., and is known towards the S.W. as the 'Cotswold Hills.' Here it forms an upland mainly of limestone, and is dissected by valleys in which lias clay is sometimes exposed. Owing to the south-easterly dip of the strata, Oxford clay covers the surface of the limestone plateau, in patches, towards the east and south. The streams crossing this region are the Evenlode and Windrush, both tributary to the Thames, and each with tributary valleys which are usually occupied by streams but sometimes partially dry. Owing to alternation of strata of different degrees of porosity, springs occur on or near the valley sides, and their distribution is important for human settlement. Wychwood Forest formerly covered nearly all this region between the Evenlode and Windrush. It is now restricted to a very small area adjoining Cornbury Park. The different geological formations show some influence on vegetation, and this can be traced in the distribution of arable and grass land before the enclosures of the nineteenth century, and is also indicated in many old field-names.

Types of villages have been classified in various ways—in this area the 'valley' or 'spring-line' type predominates. The sites of villages in this area as well as those of remains of Roman or prehistoric settlements may be considered in relation to geological formations, springs, previously forested areas, and communications.

As there are no large towns in this region, there are no great contrasts in the density of population per parish. The changes in population according to the census returns of the last 120 years should be considered in connection with the enclosure of common fields, the coming of the railways, and the character of local industries.

33. Miss C. Butler.—*Some Results of Local Lore Surveys by Oxfordshire Schools.* (With exhibit.)

A small group of village teachers and schools, mostly in remote parts of Oxfordshire, have for the last year or two been endeavouring, with the approval of the L.E.A. and with some help from Barnett House, to 'discover' their immediate neighbourhoods. They have done this on an ordered plan, as far as possible by direct observation and inquiry, but also largely using, supplementing, and comparing diagrams based on the six-inch ordnance map for their district.

Thus on tracings of outlines of fields they have inserted the local field-names—comparing these, when possible, with those given in sixteenth and eighteenth century enclosure maps—and the crops, comparing these with the geological map and with their tracings showing contours and water-supply. They have drawn and walked round the parish boundaries, trying to work out reasons for their shape; they have recorded the farm-stock (including fowls and rabbits), and means of communication (cycles, etc.). (The villages are small, and the children could get such information without becoming inquisitorial.)

These surveys are in no way finished; the process of their manufacture is not itself new, but it is believed that they have not as yet been attempted quite in this form by village schools.

The group concerned has prepared a small exhibit of the material so far collected. This is on view, and consists of (*a*) maps (mostly on tracing-paper for superimposition) and illustrations; (*b*) co-operative and individual note-books, mainly on local history, industries, and customs; (*c*) a few specimens of surviving agricultural implements (*e.g.* a breast-plough).

The object of the exhibit and of this brief paper is to show what can be done in a year or so: (*a*) to tap a comparatively fresh source of interest for country children and their elders (the surveys have given much pleasure to their makers); (*b*) to connect village-school work with village life; (*c*) to give a picture of existing conditions.

These villages, like others less remote, are in process of rapid change; and a local Domesday survey fresh from the soil, even if imperfect, may not be without value as a record of departing customs and methods.

34. Mr. Wilfrid Bonsor.—*Elfshot.*

Before the causes of disease were known, illness was often attributed to the agency of supernatural beings, and especially to the arrows of the elf-kind. Magic was employed for protection against them. The doctrine of elfshot is a characteristic of Anglo-Saxon and also of Finnish magic and medicine. With both peoples the

elves were malevolent. The term 'elfshot' was taken literally, and neolithic arrow-heads were until recent times thought to be the visible survivals of it. Sudden indisposition, stitch, cutaneous diseases, and nightmare were especially ascribed to the elves. Cattle as well as men were their victims. The Lacnunga contains two charms, one against stitch and one for nightmare, which vividly illustrate the fear with which the elves were regarded; the story in 'Heimskringla' of the death of King Vanland from nightmare produced by magical means also shows that the terms used to describe these evils—elf*shot* or night*mare*—were taken literally. With the advent of Christianity, elfin possession was equated with demoniacal possession, and the remedies employed were modified to suit the new conditions: the warts were now dipped in hallowed water, or had Masses sung over them.

Exhibits in the Department of Human Anatomy, University Museum.

(1) Objects and Skeletal Remains from Mesopotamia.

(2) Maps and Plans to show the Distribution of Villages in Oxfordshire in relation to their Geographical Situation (Miss Simpson).

(3) Maps and Plans illustrating the Progress of Regional Surveys at present being conducted in Oxfordshire (Miss Butler).

(4) Chellean Quartzites from Taivilla (W. of Algeciras, Spain) (Mr. Henry Field).

(5) Palæolithic Implements from the North Arabian Desert.

(6) Tasmanian Stone Implements.

SECTION I.—PHYSIOLOGY.

(For references to the publication elsewhere of communications entered in the following list of Transactions, see page 448.)

Thursday, August 5.

1. Prof. D. Fraser Harris.—*The Reality of Nerve-energy.*

The term 'nerve-energy' is in common use by physiologists and by writers on medicine, neurology, and psychiatry. Though other terms have been suggested from time to time, none has come into general use. 'Nerve-energy' was defined by Adrian (1922) as 'the total potential energy in the neurone available for use in the transmission of impulses.' If this definition be accepted, three questions arise: (1) What is the relation, if any, of this 'nerve-energy' to 'vital' energy, to 'biotic' energy, and to 'mental' energy? (2) Does 'nerve-energy' include the activity of afferent neurones? (3) How can this *potential* energy be measured? It is suggested that nerve-energy should be measured in terms of other forms of energy.

2. Miss H. Wells and Prof. R. J. S. McDowall.—*The Physiology of the so-called 'Psycho-Galvanic Reflex.'*

3. Presidential Address by Prof. J. B. Leathes, F.R.S., on *Function and Design.* (See p. 208.)

4. Dr. F. W. Edridge-Green, C.B.E.—*The Importance of the White Equation to the Theory of Colour-Vision.*

The trichromatic theory was founded on the white equation; that is, the equation of a mixture of red, green, and violet lights to match a white light, and in various proportions to match intermediate spectral colours. We are not, however, justified

in assuming that there are three underlying fundamental sensations. There have been numerous mathematical expositions of the trichromatic theory of colour-vision which are correct from the mathematical point of view, but the physiological aspect has been entirely overlooked. No two sets of observers have agreed on the three variables. A different construction is required for each set of facts.

As Parsons states:—'The three components theory becomes less plausible the more concrete the form it takes. We must therefore accept the theory as explaining satisfactorily either the phenomena of after-images or those of dichromatic vision, but not both.' It should also be shown that when complementary colours are combined to make white the same proportions of the hypothetical sensations should exist as in the white equation. This has not been done. Frank Allen finds that the green of the spectrum appears as a simple sensation and not as if compounded of three sensations. When we come to colour-blindness, we find important differences in the white equation. It has been assumed by many that anomalous trichromatics—that is, those who put too much red or too much green in the mixture matching white—are necessarily colour-blind, but this is not the case. Abney has classified the partially colour-blind by calculating the amount of red or green above the normal which is put in the equation, and also states that they do not agree with the normal white equation. At the Board of Trade a hundred and fifty-four cases of partial colour-blindness were tested by me on this point; forty-seven of this number matched the normal equation with normal simple white, ninety-two matched the normal equation when luminosity of simple white was either reduced or increased, fifteen would not match normal equation at any point of luminosity of simple white. It will be seen, therefore, that over ninety per cent. matched the normal equation, either with the normal simple white or when the luminosity of the simple white was either reduced or increased. In each case an erroneous white equation was made as well.

If we regard the colour-vision centre as arranged in a similar manner to the spectrum—that is, one side being responsive to impulses caused by red light and the other side to impulses caused by violet light, and the intermediate portions to orange, yellow, green, and blue lights respectively—we have a theory which will explain all the facts, including those of Burch and Roaf.

5. Prof. H. E. Roaf.—*On the Threshold for Hue Discrimination of Normal and Hypo-chromatic Individuals.*

Friday, August 6.

6. Joint Meeting with Section D (*q.v.*) for Papers on *The Value of Tissue Culture in Biology.*

Demonstration of Microscopical Preparations by Prof. Ch. Champy.

7. Sir Jagadis Chunder Bose, F.R.S.—*The Action of Alkaloids and of Cobra-venom on the Pulse-beat of Plant and Animal.*

The life-mechanism of the seemingly impassive plant has hitherto been regarded as quite different from that of the restless animal. The devising of suitable highly sensitive apparatus has permitted the revelation of hitherto unsuspected life-mechanisms within the plant.

In the animal there are three striking reactions—muscle-contraction, conduction in nerve, and the rhythmic pulsation of the heart with the circulation produced thereby.

Just as there are marked differences in the contraction of different muscles (*cf.* the wing-muscles of the falcon and of the domestic fowl), so in the plant kingdom we find a very active motile organ in mimosa while in the bean there is little or no activity. Differential staining shows that the degree of activity runs just parallel with the amount of a highly oxidisable substance present in the motile organ.

With regard to conduction, if suitable stimuli are used, rather than such violent methods as knife-thrusts, there is a remarkable relation between conduction in plant and in animal. In the plant, too, excitation takes place at the kathode at make and the anode at break; the passage of the impulse can be arrested, for example, by a

constant current. The ascent of sap is not wholly a physical but fundamentally a physiological process, not essentially different from the mechanism of propulsion of blood in the animal. The parallelism extends to such points as the necessity of an internal hydrostatic pressure to evoke the rhythmic contraction, the association of electrical with mechanical changes, and the stimulant or depressant action of substances which have these effects on the animal heart.

The results prove that in these three striking reactions, the mechanism of life of the plant is essentially similar to that of the animal. The simpler type of plant organisation offers experimental advantages, and such experiments may well lead to the solution of perplexing problems.

8. Discussion on *The Relationship of Vitamin B to 'Bios.'*

(*a*) Prof. R. A. Peters.

Since, at the beginning of the present century, Wildiers, in the laboratory of Professor Ide, put forward the view that yeast needs, for rapid growth, traces of some unknown organic constituent, 'bios,' there has been much work and considerable dispute on this topic. It has been shown by G. L. Peskett that, while Medium F. (Fulmer, Nelson and Sherwood) does not grow all yeasts efficiently, the addition to this medium of small amounts of anti-neuritic concentrate induces enormous acceleration of the multiplication. Such a 'stimulant' effect can be obtained from the preparation even after inactivation, by alkali, of its anti-neuritic properties. Such anti-neuritic concentrates therefore show 'bios' activity, but the reverse is not true.

(*b*) Mr. G. L. Peskett.

(*c*) Miss Reader.

A basal synthetic medium for the cultivation of *Streptothrix corallinus* was devised. To this additions of anti-neuritic concentrate (Kinnersley and Peters) were made. As little as 1/40,000 of a 'pigeon-dose' in 20 ccs. of the synthetic medium stimulated growth, while when greater doses were used the organisms were of abnormally large size.

Parallel tests, during fractionation of brewers' and of bakers' yeast, show that anti-neuritic power (pigeons) and growth-producing power (*Streptothrix corallinus*) run parallel as far as a concentrate of which 0·2 mgm. contains one 'pigeon-dose.' Both 'factors' are inactivated by alkali; indeed, the growth-producing factor for *S. corallinus* may be identical with the anti-neuritic factor.

(*d*) Miss Orr-Ewing.

The addition, to nutrient agar medium, of anti-neuritic concentrates did not induce the growth of either Meningococcus, Gonococcus, or Bacillus Influenzæ. Meningococcus will grow on charcoal-extracted meat-extract medium containing no vitamin (pigeon test) and no growth-producing factor for *Streptothrix corallinus*. The Meningococcus, therefore, does not need anti-neuritic vitamin for growth. By a process of exclusion, it is concluded that the gonococcus-growth-promoting factor present in blood and other fluids is not anti-neuritic vitamin.

9. Prof. J. C. Drummond.—*Observations on the role of Vitamin B in Animal Nutrition.*

Monday, August 9.

10. Discussion on *Reflex Posture.*

(*a*) Dr. F. M. R. Walshe.
(*b*) Prof. J. A. Gunn.
(*c*) Prof. Sir Chas. S. Sherrington, O.M., G.B.E., F.R.S.
(*d*) Mr. D. Denny-Brown.

11. Dr. W. W. Payne and Dr. E. P. Poulton.—*The Physiological Basis of Visceral Sensation.*

12. Dr. H. M. Vernon.—*What is the best Index of Comfort with regard to Atmospheric Conditions?*

In the last few years a large number of observations have been made in America (Pittsburgh) on what is termed 'effective temperature.' The subjects of experiment passed backwards and forwards between two chambers, in which the temperature, humidity, and degree of motion of the air could be changed independently. Various combinations of these qualities were effected, such as produced similar degrees of comfort, or of discomfort, in the subjects, and as the result of numerous experiments charts were constructed from which it is possible to combine any degree of dry-bulb and wet-bulb temperature, and of air velocity, into a single expression, the 'effective temperature.[1] However, this expression is not usually an accurate index of comfort, as it makes no allowance for acclimatisation. The cooling power of the air, as estimated by means of the dry kata-thermometer, does include a considerable allowance for acclimatisation, and it is usually a much better index of comfort than effective temperature. This was proved empirically by making thousands of observations in factories at various seasons, both on the investigators themselves and on the workpeople.[1] Even the kata cooling power does not make sufficient allowance for acclimatisation; and whilst a medium sensation of air movement is produced, during mild weather, by air with a cooling power of 6, in cold weather the cooling power has to be raised to 7 in order to produce a similar sensation, and in summer weather it has to be lowered to 5. The dry-kata cooling power is not a good index of comfort for men covered with perspiration, the result of hard muscular work. For them the wet-kata cooling power is the best index. This was proved by observations on miners engaged in hewing coal. Such men cannot work continuously, and it was found that when working under pleasant atmospheric conditions (at a wet-bulb temperature of 66° and a wet-kata cooling power of 15 to 18) they rested, on an average, for seven minutes per hour. Under worse conditions they rested longer and longer, till at a wet-bulb temperature of 79° (and wet-kata cooling power of 6.4) they rested twenty-two minutes per hour. Also they took 20 per cent. longer time to fill the coal-tubs under these conditions than under the best conditions, and it was calculated that their working capacity was 41 per cent. less. Under intermediate conditions intermediate values were obtained. Observations were made on 138 colliers in all.[2]

13. Prof. W. H. Wilson.—*The Influence of Posture on the Volume of the Reserve Air.*

The volume of the reserve air in a man of average vital capacity varies, with the posture of the body, from a probable minimum of 350 cc. in the recumbent supine posture to 1550 cc. in the perfectly erect posture. The variation with posture changes is ascribed to the fact that the point of equilibrium of the different elastic forces acting directly or indirectly on the lung alters with each change of posture. This variation is of importance not only with regard to the estimation of the effect of ventilation with given volumes of air, and of the dead space, but also with regard to the study of abnormalities of breathing in certain pulmonary and cardiac affections.

Tuesday, August 10.

14a. Dr. H. M. Vernon and Mr. J. J. Manley.—*The Measurement of Variations in Air-Movement and Temperature.* (Demonstration.)

14b. Dr. H. M. Vernon and Mr. J. J. Manley.—*An Improved Type of Electric Miners' Lamp.* (Demonstration.)

[1] *Cf.* Medical Research Council Special Report, Series No. 100, and Report No. 35 of Industrial Fatigue Research Board.

[2] *Cf.* Report to be published by Industrial Fatigue Research Board.

15. Mr. F. Haynes.—*Changes in the Lungs of Pit-ponies.* (Demonstration.)

16. Dr. W. A. Aikin.—*The Application of Normal Physiology to Speaking and Singing.*

17. Miss S. Cooper and Mr. D. Denny-Brown.—*Responses to Stimulation of the Cerebral Cortex.*

18. Dr. J. S. Haldane, F.R.S.—*Lecture on Acclimatisation to High Altitudes.*

SECTION J.—PSYCHOLOGY.

Thursday, August 5.

(For references to the publication elsewhere of communications entered in the following list of Transactions, see page 448.)

1. Prof. C. Spearman, F.R.S.—*The Origin of Error.*

2. Prof. A. Michotte.—*Observation and Analysis of Mental Facts.*

3. Dr. F. Aveling.—*Brief Notes on the Psychogalvanic Phenomenon so far as this is relevant to Psychology.*

Correlation of the P.G.R. with Mental Process; Physiological Process involved; Ascertained Psychological and Physiological Sequences; Difficulties in the way of scientific handling of the facts; Distinction of Mental Process as Cognitive and Appetitive; Further Distinction of Orectic Process as Conative and Affective; Relation of the P.G. Phenomenon to Conative Process; The James-Lange Theory; Objections of Wechsler to the Conative Significance of the P.G.R.; The Concept of the Unconscious; Ambiguity of Terms; General Evidence from Researches; Further Evidence from a Research on Conation and Volition; Theoretical Conclusions of Importance Indicated; Data of ‘ Brief Notes ’ submitted for Discussion.

4. Dr. Marguerite E. Bickersteth.—*Colour Imagery.*

5. Prof. W. McDougall, F.R.S.—*Intelligence in Rats.*

6. Dr. H. Banister.—*A new Hypothesis of the Localisation of Sound.*

Two factors appear to be at the basis of sound localisation, viz., time-difference at the ears for short sounds (clicks), and for continuous sounds of low pitch, and intensity differences for sounds of high pitch. To explain these we must turn to the physiology of the sensory elements.

It seems probable that nervous impulses in the auditory nerve are discrete. They are initiated by the movements of the cilia of the hair-cells on the Basilar Membrane. Assuming that the impulses are initiated when the cilia are in a certain phase of their cycle, the impulses from the two ears will reach their respective sensory areas in the brain at time-differences equal to those between the arrival of the sound-waves at the ears. This gives localisation by time-difference. Now nervous impulses cannot follow one another along a nerve at time-intervals less than the Refractory Period. If the cilia are in the position for initiating an impulse during the Refractory Period, that impulse will not be initiated. For these frequencies localisation by time-difference will be ambiguous. Now, as Rayleigh has shown, the head normally produces a sound-shadow for notes of these higher frequencies—no appreciable sound-shadow is produced by the head for sounds of low pitch. The resulting

intensity differences give the Local Sign for sounds of high pitch. Increases of physical intensity are transformed into increases of psychological loudness, either through more fibres of the Basilar Membrane being set into motion by the louder sound, thus setting up an increased number of nervous impulses, or by stronger impulses being produced, or by both more and stronger impulses being originated.

These two separate systems (time-difference and intensity) will account for the facts of localisation.

7. Dr. R. D. Gillespie.—*Heredity and Environment in the Production of Morbid Mental Reactions.*

The estimate of the relative importance of inherited (instinctive) and acquired reactions has been changing in recent years. The work of Watson and others has suggested a comparatively limited instinctive endowment in man, in contrast with the assumptions of most writers. The point is of importance in pathological psychology also, not only because a wider and more significant incidence of acquired reactions would make for greater hopefulness in prevention and therapy, but because in pathological psychology, where certain reactions, being morbid, are very obvious, and so have a more easily traceable history, an opportunity is afforded for contributing something to the problem in psychology generally. An inquiry into the histories of fifty-three psychoneurotic patients showed that in seventeen of them, many of the leading symptoms could be demonstrated to be the revival in adult life of reactions impressed upon them by early environmental (especially familial and scholastic) influences. In the majority of the seventeen cases there were distinct evidences of mental instability in the ancestors and collaterals. But whether or not this instability be considered heritable in a general way, the cases under investigation showed that in them outstanding specific morbid traits were derived directly from personal contact with parents and others in the early environment. In these psychoneurotics the conclusion seems justifiable that the illness is attributable in type at least to acquisition, while its actual occurrence depends in part on the acquired habits of reaction. It is obvious that what at first glance appears to be inherited in an unstable family may simply be transmitted by personal contact. The conclusions are of some practical significance for the prevention of mental illness.

Friday, August 6.

8. Prof. C. Burt.—*Estimations of Temperament and Character.*

9. Dr. J. C. Maxwell Garnett, C.B.E.—*The Psychology of Patriotism.*

This fortress built by nature for herself
Against infection and the hand of war;
This happy breed of men, this little world,
This precious stone set in the silver sea.

The land we live in, the people who belong there, their ways of life and habits of mind—for all these we have a sentimental attachment. We feel proud, if they prosper; dejected, if they fail; angry, if they are attacked by word or deed; anxious, if they are in danger. Here is a plain case of a ' sentiment,' as Mr. Shand calls ' an organised system of emotional tendencies centred about the same object.'

The precise nature of the object is discussed in the paper. Here it is enough to say that these emotional tendencies are just what we call patriotism, if only their object is sufficiently clear-cut. York or Devon, Kentucky or Idaho, with their peoples and their ways of life, are not distinct enough. But Switzerland is; Canada is, or soon will be; while England used to be English, and now, officially at least, is British.

Patriotism, then, is a sentiment. Like other sentiments, it is not innate. On the contrary, it is the product of environment and education. Among environmental influences that tend to produce intense patriotism are sharp geographical boundaries, distinctive race or language, a noble literature, a glorious tradition with a period of intense endeavour and strong emotion, common ideals and a common purpose, and, last but not least, the nation-state where people who already, as a nation, have dis-

tinctive ways of life and habits of mind, as a state manage their joint affairs and so reinforce their common characteristics. No one of these things is essential. The Poles, until lately, were divided between three states, and to-day Poland is without geographical frontiers. The Swiss have at least two races and three languages. A few years in the United States and a common purpose to put 'America first' often suffices to make Finns or Slavs or Latins into patriotic Americans with a nationality resembling Anglo-Scotch.

It is good for the human race that its most important divisions should be psychological—into nations with their different patriotisms—rather than racial, or political; provided that the variety is within, and subordinate to a unity, a spiritual commonwealth of nations. Then patriotism will never override justice; and 'allegiance to one's country, even to its crimes,' will not rank before allegiance to truth and to fair play. This result is helped by cross-groupings among the nations: common religion, or language, or occupations, or intellectual pursuits, or even political ties.

10. Presidential Address by Dr. J. Drever on *Psychological Aspects of our Penal System.* (See p. 219.)

11. Mr. R. J. Bartlett.—*The Judgment of Value of Individual Advertisements.*

In an inquiry undertaken for the National Institute of Industrial Psychology an attempt was made to grade advertisements in order of 'attracting holding' power. To achieve this a 'scale' was prepared. Advertisements when judged for a particular feature tend to show a normal scatter; 417 advertisements, separated into seven grade groups by comparison with the scale, gave a close approximation to the binomial point curve $(1+1)^6 \times \frac{417}{64}$. In preparing the scales it was found that, although in many cases there is extreme variability of judgment from subject to subject, there is close agreement with reference to others up to a division into seven grades. These 'Firm' advertisements were used in the formation of the 'scales.' The method of paired comparison becomes too tedious and for this reason unreliable, when the items to be graded exceed twenty. The following method was therefore evolved and used: The advertisements were sorted into three groups—good, medium, poor. Each group was then sorted into three sub-groups. The lower sub-group of 'good' and the upper sub-group of 'medium' were amalgamated, as were also the lower 'medium' and upper 'poor.' The result is seven groups, the sizes of which approximate to normal distribution. The process can be continued giving fifteen groups, then thirty-one and so on, where, if n=number of sortings and N= number of groups,

$$N = 2^{n+1} - 1.$$

With advertisements none but well-practised subjects are able to carry the procedure beyond the second stage of seven groups with reasonable consistency. The scales are shown and some analysis of the basis on which judgments are formed is given.

12. Mr. A. Stephenson.—*Some Observations on Accidents in Industry.*

13. Mr. A. Angles.—*Restriction of Output.*

Restriction of output is a phenomenon in industry which has attracted widespread attention since the post-war depression in trade. There can be no doubt as to its existence, but there is a considerable doubt as to its extent and importance. In factories where it is practised it appears to be a defensive action by a group of workers against conditions which they believe to be unfair. In no case within the experience of the National Institute of Industrial Psychology has restriction of output been attributable to the particular trade union, as such. It is usually brought about by a strong feeling of class loyalty which in known cases has even overcome individual self-interest. If restriction is being practised it is usually indicated by the persistence of a remarkable uniformity in output. The workers advance many reasons for this policy, but two of them are sufficiently frequent to be outstanding:

(1) Fear of rate-cutting: Instances are on record where employers have reduced rates in order to keep the workers down to a certain minimum.

(2) Fear of unemployment, or, increased short-time. The workers may spread the work out (if it is limited in amount) so that the time-rate workers shall have the benefit of longer hours and more pay.

Other reasons are: The fear of discharge of less competent workers.
General dissatisfaction with present conditions.
Influence of the foreman.
Satisfaction with present earnings.

These general conditions and the system of wages vary enormously according to the efficiency of the management, but where the 'mental atmosphere' of the factory is good, restriction of output will very rarely be found.

Monday, August 9.

14. Prof. C. Lloyd Morgan, F.R.S.—*Individual and Person.*

Something will here be said in support of the suggestion, elsewhere made but nowise new, that a point of view is permissible from which personality and individuality may be regarded as limiting concepts that are poles asunder. Each of us in concrete being swings somewhere between these limiting extremes.

Since each of us is both individual and personal, the two words may often be used, interchangeably in current speech, as convenient literary synonyms. None the less there still lingers some touch of the original dramatic usage of the word 'person'—and that not only in such derivations as 'impersonate' and 'personify.' The stage helped not a little to socialise a concept which implied a communal voice that spoke through the mask of the individual actor and served to evoke a communal response. It is this social and communal factor that may be emphasised by rendering more explicit in technical usage the distinction between individual and person. In the sense intended, alike in expression and in the impression conveyed, alike in the manner of outlook and in that to which this outlook has reference, individuality is unique, personality is, in increasing measure, comprehensive.

Whereas, then, under this distinction, individuality is unshareable, personality is what we share with others, within some type, under inter-subjective intercourse. Whereas *qua* individual the self is 'perfectly impervious to other selves' (Pringle-Pattison), *qua* person the self is communal, sharing the outlook and voicing the judgment of others. Whereas individuality sets the limit of uniqueness, personality approaches the limit of all-embracing comprehensiveness.

15. Prof. E. Rignano.—*La Psychologie dans ses Rapports avec la Philosophie et avec la Science.*

16. Mr. F. C. Bartlett.—*The Social Psychology of Leadership.*

17. Joint Discussion with Sections D and H on *Heredity in its Physical and Mental Aspects.* (See pp. 366, 390.)

Tuesday, August 10.

18. Prof. W. McDougall, F.R.S.—*An Experiment supporting the Lamarckian Hypothesis.*

19. Dr. W. Brown.—*Personality and Value.*

Any theory of personality is faced with a special problem in determining the position of values—goodness, truth, beauty—and of religion within the circle of individual experience. The present paper deals with such aspects of this problem as the relation of normal and pathological, the time-factor in the appreciation of value,

intuition, faith, and mysticism. It briefly discusses Freud's recent theory of the 'ego-ideal' or 'super-ego' in illustration of the contrast between a psychological and a philosophical treatment of the problem of value.

20. Dr. Mary Collins.—*British Norms for Pressey's XO Test.*

21. Miss J. Lodge.—*The Illusion of Warmth Test for Suggestibility.*

22. Miss W. Spielman.—Lecture on *Recent Progress in Vocational Selection.* (Illustrated.)

The older methods of vocational selection—entirely unscientific or quasi-scientific—are compared with modern methods employing mental and physical tests. Illustrations of various types of tests and of the results obtained in practice are given to show the recent trend of development. A description is also given of the study that has recently been made of the technique of the interview (including rating-scales for the assessment of personality) to supplement the tests.

Attempts are made to weigh the economic and social advantages of the new method and to forecast its future lines of development.

23. Dr. E. Pickworth Farrow.—*Psycho-analysis by a Process of Self-analysis and some Results obtained by it.*

This paper describes a method of self-analysis by following which any mentally fairly healthy person should eventually be able to remember quite clearly one or more incidents which occurred to him when he was only about six months old—naturally, a long time before he was able to speak.

Briefly, the method consists in writing down absolutely any and every thought which occurs to one on blank paper for periods of one or two hours at a time and continuing this process over a number of periods. What happens is, apparently, that by this process, affect or feeling gradually becomes completely worked-off the memories of recent happenings and, as this process continues, the mind gradually remembers incidents further and further back in one's life. There is no doubt whatever about the validity of a certain type of early recollection which is obtained in this way, for the recollections in cases of this type are so clear and definite—both of the incidents in question and of a large number of the circumstances surrounding the individual at the time of occurrence of the incidents. In very many cases subsequent verification of these surrounding circumstances may be obtained from one's parents, and one may later also recognise, or realise the existence of, various objects about the house which 'first' appeared in the analytic recollections of the incidents—*i.e.* various definite objects to the existence of which one had previously been comparatively blind, subsequent to the occurrence of the incidents, owing to repressed emotion associated with these early incidents, until this repressed emotion had been removed by the analytic process.

The results obtained by this process of self-analysis strongly confirm Prof. Freud's results concerning the mode of working of the human mind, except that they rather suggest that Prof. Freud may perhaps not have given due or proportionate weight to the egoistic or self-preservative group of instincts. The paper concludes with an appeal to all psychologists to try such a method of self-analysis upon themselves, for the results they would obtain are certainly extremely interesting and beneficial, and they might also be very valuable and important. This method of psychological research needs no apparatus of any kind—only patience, a pen, and some paper—and thus anybody can follow it and test the ultimate definite recollection of extremely early incidents for himself. A detailed description of this process appeared in the *British Journal of Medical Psychology*, Vol. V., Part 2, 1925; and some results obtained by the reader of the present paper through following it have appeared in the *International Journal of Psycho-Analysis*, Vol. VI., Part 1, 1925; *The Medical Press*, April 29, 1925; the *Journal of Neurology and Psychopathology*, August 1925; the *Journal of Mental Science*, October 1925; and in the *Internationale Zeitschrift für Psychoanalyse*, Bd. XII., Heft 1, 1926.

SECTION K.—BOTANY.

(For references to the publication elsewhere of communications entered in the following list of Transactions, see page 448.)

Thursday, August 5.

1. Presidential Address by Prof. F. O. Bower, F.R.S.—*1860–1894–1926.* (See p. 231.)

2. Dr. T. F. Chipp.—*Some Dangers of Forest Destruction in the Tropics.*

3. Prof. D. H. Campbell.—*The Nature of the Sex-organs of the Archegoniates.*

1. This paper offers some suggestions as to the possible derivation of the sex-organs of the Archegoniates.

2. Hepaticæ and Mosses have the antheridium and archegonium quite free, while the Anthocerotes have these organs submersed and more nearly resemble in this respect the lower Pteridophytes.

3. The theory of the derivation of the Archegoniates from Green Algæ with plurilocular gametangia is probably the most plausible; the comparison with the gametangia of the Phæophyceæ can hardly imply a real relationship.

4. If the derivation of the sex-organs of the Archegoniates from plurilocular gametangia is accepted, it may be questioned which type is more primitive, the free or the submersed—or have these two types developed independently?

5. The nearest approach to the algal gametophyte is found in the Anthocerotes and lower Pteridophytes. It may be that the gametophytes of the latter more nearly resemble the ancestral algæ than do any existing Bryophytes.

6. Among the Anthocerotes, the solitary antheridium is probably a more primitive condition than that in which the mother-cell divides into several antheridia.

4. Prof. F. L. Stevens.—*Tropical Fungi of the Western Hemisphere.*

It has been the author's good fortune to devote a considerable time to tropical collecting; five months in the Hawaiian Islands, some two years in Porto Rico, with visits to other Caribbean Islands, Martinique, Mona, Trinidad; some months in Central America, Costa Rica, Panama, and British Guiana, Venezuela, Colombia, Ecuador, Peru. A range in altitude from sea-level to 16,000 ft. including the headwaters of the Amazon at an altitude of 1,500 ft. was covered.

A very great diversity naturally is met. Of greatest interest, perhaps, are the unusual forms, and especially the transition or bridging forms between genera or families.

Lantern slides illustrating several such transition forms pertaining to the following groups are given: Meliolinæ, Hemisphæriaceæ, Trichopeltaceæ, Dothideales, and the genera Anisochora, Polystomellopsis, Anomothallus, Yoshinagella, Marasmius, Shropshiria, Clypeodiplodina and Dothidina. The method of using aluminium driers is outlined.

5. Prof. F. E. Weiss, F.R.S.—*Unilateral Inheritance in Ranunculus auricomus.*

The Common Goldilocks (*Ranunculus auricomus*) occurs in two forms, one with five large yellow petals, and the other apetalous, the sepals being green on the outside but yellowish on the inside. The petaloid form has radical leaves finely dissected, like the leaves of a buttercup; the apetalous form has leaves which are very little divided. While these two varieties are very distinct, one finds plants occasionally which appear to be of an intermediate type and possess a varying number of petals, from one to five. It would appear as if these had been produced by natural crossing of the two varieties.

To test this supposition reciprocal crosses were made with the two varieties, plants being used which had been selfed for several generations and proved to breed true to type. The seedlings from the outset showed a considerable difference. All those derived from crossing the petaloid form with pollen of the apetalous variety had dissected leaves, while those resulting from the apetalous form pollinated with pollen from the petaloid variety had almost undivided leaves. There was thus a marked contrast in the reciprocal crosses.

The offspring with divided leaves all bore flowers with distinct petals, but the number of the latter showed considerable variation, the average number being three or four, with a variation from one to five. In no case were they apetalous. These would therefore represent the forms occasionally found in Nature.

On the other hand, the offspring derived from the reciprocal cross showed no intermediate condition, but were, with one exception, all apetalous and exactly like the female parent. As there seemed a possibility that this striking occurrence might be due to apogamous reproduction, castrated plants were left unpollinated, but no seed-production took place. Two further generations have been bred from these crosses, but the plants continued to bear apetalous flowers and leaves with very slight incisions exactly like the female parent from which they have sprung.

This crossing therefore seems to result in what Blaringhem calls 'unilateral inheritance,' similar to the results obtained by Gaertner in the case of *Lychnis flos cuculi*, by Millardet with various species of *Fragaria* (fausses hybrides), and by Griller in his crosses of *Vitis* and *Ampelopsis*.

6. Prof. J. Percival.—*Aegilops × Wheat Hybrids.*

The author has obtained hybrids of *Aegilops ovata* with the wheats Wild Emmer (*Triticum dicoccoides*), Emmer (*T. dicoccum*), Macaroni Wheat (*T. durum*), and Bread Wheat (*T. vulgare*), the *Aegilops* being the mother plant. In almost all morphological characters the hybrids were intermediate between the two parents. Reciprocal crosses were unsuccessful.

Meiosis and pollen formation in the hybrids *A. ovata* × *T. dicoccum* and *A. ovata* × ***T. vulgare*** **have been studied.**

Afternoon.

Excursion to Swinford Bridge (to study aquatic plants).

Friday, August 6.

7. Prof. H. H. Dixon, F.R.S., and Mr. T. A. Bennet-Clark.—*Electrical Stimulation and Response in Plant Tissues.*

The passage of a current through a tissue leads to a change of electrical resistance and to a change of permeability. The relationship between change in resistance and the intensity and duration of the current has been examined. 'Very small' stimuli cause an increase in resistance, 'larger' stimuli cause a decrease. There is a definite period of development of the maximum effect, followed by a recovery. The same quantity of electrical energy is found to be the more effective the higher the potential at which it is applied. The change in resistance in different regions and in different directions in the tissue, the effects of a second stimulus on tissue already stimulated, also temperature and seasonal effects on resistance and on sensitivity, have been investigated.

8. Dr. Malcolm Wilson and Miss E. J. Cadman.—*Recent work on Reticularia and other Mycetozoa, and its Bearing on the Position and Classification of the Group.*

In *Reticularia lycoperdon* there is no definite myamœboid stage. The fusion takes place between gametes which are identical with the swarm-cells. Before the fusion of the gametic nuclei the zygote coalesces with a number of swarm-cells, the nuclei of which usually undergo direct division and are ultimately digested. Later ingestion of entire swarm-cells may take place. The fusion nucleus in the young

zygote rapidly divides and the plasmodium soon enters the wood. After emergence, portions of the protoplasm degenerate and give rise to the pseudo-capillitium and wall of the sporangium. In the remaining portions the nuclei undergo two successive divisions before spore formation, constituting a typical meiosis.

Reticularia is regarded as a primitive type among the Mycetozoa.

9. Dr. E. J. Collins.—*Sex Distribution and Inheritance in Silene mutans in Relation to the Sex Problem in Plants.*

In *Silene mutans*—a reputed trioecious species—four types of plants have appeared during this investigation, carried on since 1917.

(*a*) Hermaphrodite.

(*b*) Those bearing hermaphrodite and female flowers together with flowers with a reduced number of stamens, frequently with a bias.

(*C*1) Seeding females.

(*C*2) *Non-seeding females.*

Non-seeding females come in practically all progenies whatever the parentage. Investigation has shown that the embryo-sac is not organised in this type.

The predominantly female type self-pollinated gives a progeny in which maleness is reduced or entirely absent, irrespective of the sex form of flower made to bear the seed. With pollen from a plant constant in its hermaphroditic condition, maleness in the progeny is increased.

No purely male form has appeared at any time.

10. Discussion on *Sex-determination in Plants.*

(*a*) Prof. Dame Helen Gwynne-Vaughan, D.B.E.

In several dioecious species of *Lychnis*, in *Elodea* and in *Rumex*, the sporophyte of the male has been shown to possess X and Y chromosomes, and that of the female XX; the case for sex-determination here seems to be strictly comparable with that in animals. While there is only one kind of embryo-sac, there are pollen grains of two types, male-producing and female-producing. A possible comparable condition is found in *Mucor*.

In monoecious sporophytes, on the other hand, there is at present no evidence of the part played by the chromosomes in the development of sex, or whether monoecious and dioecious species of the same genus differ essentially in this respect.

Among homosporous plants with an asexual sporophyte, the gametophyte may be monoecious or dioecious. In *Sphærocarpus* the nuclei of archegoniate plants possess a large X chromosome, while in antheridial plants the nuclei contain a smaller Y element; there is evidence that both occur in the nuclei of the sporophyte and that X and Y are synaptic mates. A similar condition is indicated in dioecious mosses and in *Phycomyces*. Comparison with the male plant of *Lychnis* is of interest.

In certain Basidiomycetes the basidia bear four spores, which have respectively the constitution AB, Ab, aB, and ab; a sporophyte is formed only when fusion brings about the combination AaBb, and the existence of four sexes, and even of larger numbers, has been inferred. Such Basidiomycetes lack gametangia and are regarded as pseudapogamous forms in which all trace of sex in the ordinary sense has disappeared.

(*b*) Dr. Heslop Harrison.

Whilst it is true that in most of the Salicaceæ, as far as examined, sex chromosomes have been discovered, and that the conditions are much the same as in animals, the mere possession of such chromosomes does not explain the whole of the facts. In the polyploid Salices, for example, the preponderance of female plants is very great. This seems the more remarkable when it is realised that the possession of a simple XY group characterises the males. Hence differential growth of pollen-tubes from female-producing grains, and similar phenomena, must play a part.

Again, in spite of the fact that in the Capreæ group of Salices the tetraploid species *S. aurita* and *S. cinerea* possess an XY pair in the male, up to the present a similar pair has evaded detection in *S. Caprea*, presumably the more primitive form from which *S. aurita* and *S. cinerea* have been derived. This would suggest that the *S. Caprea* is in an indifferent condition, and would account for the marked oscillation in sex

seen in this species, which, under the influence of Eriophyid mites, produced intersexes. Cuttings from such intersexes have yielded purely male and purely female shrubs.

In willow hybrids the excess of females is often very great, and in many cases the males have never been detected or reared. This suggests a switch-over of the heterogametic sex comparable with the results of my Lycia-Nyssia crosses in the Lepidoptera.

(*c*) Prof. H. Kniep.

In the dioecious Phanerogams the sex-determination of the diplonts (megasporophytes and microsporophytes) can be explained on a Mendelian basis. This view is not contrary to the fact that alteration of the relative number of sexes or complete change of one sex into the other one is possible by variation of external factors. Every plant contains the potentialities of both sexes, its development depending on factors called realisators, the effect of which is evidently to be influenced by the environment.

Amongst the Cryptogams the Fucaceæ may be compared with the Phanerogams and the Metazoa concerning sex-determination.

In the diploid phase of the dioecious Musci no sexual tendency is predominant; this is proved by the fact that the gametophytes produced by experiment are monoecious. In the Liverworts, on the contrary, one case is established in which the one sex predominates over the other one in the gametophytic state.

Great differences regarding sex-differentiation and sex-determination exist in the Thallophyta. Genotypically—and not genotypically—caused determination of sexes is neither in connection with the phylogenetical development of plants nor with the degree of differentiation of sexes. In the Volvocales, for instance, we find both cases in closely related genera: Chlorogonium, Gonium, and Pandorina are isogamics and show genotypical sex-separation. In the anisogamic Eudorina the sexes are also determined genotypically, but not in the isogamic Stephanosphæra and the oogamic Volvox.

Hybridisation experiments render it possible to establish the nature of sex also in cases in which other methods fail (*Ustilago nuda*). The homothallic and the heterothallic states are not always so sharply separated as in the Mucorineæ (Coprinus).

(*d*) General Discussion.

10a. Dr. R. T. Gunther.—*The Herbal of Apuleius Barbarus.*

The drawings of plants in the manuscript Herbal of Apuleius Barbarus, known as MS. Bodley 130, are believed to have been executed about the year 1100 in the Abbey of Bury St. Edmunds, and must therefore be regarded as the earliest English plant-drawings known. Two types of drawing are distinguishable: (*a*) Conventional figures, crudely executed and coloured, which, from having been repeatedly recopied, have lost all semblance to the plants which they are supposed to represent; some of these appear to preserve the Discoridean tradition of plant illustration, (*b*) Naturalistic figures which have obviously been drawn direct from the living plant.

The MS. has recently been reproduced in facsimile by Captain Spencer Churchill for distribution to members of the Roxburghe Club.

11. Mr. W. C. F. Newton and Miss C. Pellew.—*Primula Kewensis and its Derivatives.*

The original *Primula Kewensis* was a sterile hybrid between *P. floribunda* Wall. and *P. verticillata* Forsk. The tetraploid *P. Kewensis* owes its origin to somatic doubling of the chromosomes in branches of the sterile plant. Each chromosome is thus represented twice, and as these identical chromosomes pair in the reduction division the tetraploid hybrid breeds true. This plant is not an example of the production of a tetraploid form as the direct result of hybridisation.

Aberrant plants which have gained or lost a chromosome are occasionally produced, and triploid plants have been produced by back-crosses. From these plants and their offspring the effect of loss or gain of particular chromosomes, as well as of interchange between *verticillata* and *floribunda* chromosomes, can be determined.

12. Mr. C. D. Darlington.—*On the Cytology of the Cherries.*

Sour-cherry seedlings have double the chromosome number found in sweet cherries, while in hybrids between the two types various intermediate numbers occur. Of

thirty varieties studied, edible and ornamental, not one shows perfect pairing of chromosomes at maturation, most being aneuploid. In those with higher numbers—sour cherries and 'Dukes'—the phenomena of tetraploidy are clearly exhibited.

It appears that the three groups, sour, sweet, and 'Dukes,' have been obtained by rearrangement, within the possible limits, of the three, partially homologous, series of chromosomes, two contributed by *Prunus cerasus* and one by *P. avium*. The conclusion reached, that all existing kinds of domestic cherries owe their origin to hybridisation of the parent species, is strengthened by morphological considerations.

13. Mr. R. J. Chittenden.—*The Inheritance of Chlorophyll Aberrations in Pelargonium.*

Chlorophyll aberrations, though similar phenotypically, may show either simple Mendelian inheritance or non-Mendelian bi-parental plastid inheritance in which somatic segregation of the parental character occurs in the F_1 plants. In the non-Mendelian cases the phenotypic appearance is due to the plastids alone. The genetic character of the nuclei is masked, but can be ascertained by suitable crosses with Mendelian varieties, when—allowing for the occurrence of variegation and whole-coloured seedlings of that tissue type known to be due to plastid inheritance—the nature of the nucleus can be determined by the types of segregates represented in the progeny.

14. Dr. H. Holden.—*Observations on the Morphology of Ankyropteris Corrugata.*

Ankyropteris corrugata is a small zygopterid fern with a stem stele which is cylindrical except where its symmetry is disturbed by the departure of leaf-traces. The petioles are given off in two series and branch dichotomously. Both stem and petioles bear aphlebiæ which appear to have been protective in character. Three types of hair are borne by the petioles and aphlebiæ, namely : (*a*) Delicate branched ones, (*b*) stout hispid ones, (*c*) large hairs with dilated bases which suggest an early stage in the evolution of ramenta.

Saturday, August 7.

Excursion to the Berkshire Downs.

Sunday, August 8.

Afternoon.

Excursion (with Sub-section K*) to Bagley Wood.

Monday, August 9.

15. Dr. H. Wager, F.R.S.—*Carbon Assimilation in the Blue-green Algæ.*

Since the discovery, by Errera, many years ago of the existence of glycogen in the cells of species of the blue-green algæ, evidence has been brought forward to show that in this group of plants glycogen is probably a product of carbon assimilation. In the present paper this evidence is summarised, and further experiments, including the growth of specimens under different coloured-light filters, both in the presence and absence of light and carbon dioxide, all of which tend to support this conclusion, are described. The spectroscopic examination of various species also shows that, in relation to the formation of glycogen, the light rays absorbed by the phycocyanin colouring matters, as well as those absorbed by the chlorophyll, are concerned in the process.

16. Dr. W. Brown and Miss C. C. Harvey.—*On the Resistance of the Cuticle to Penetration by Fungal Hyphæ.*

The failure to demonstrate the presence of any cuticle-dissolving substance and the evidence derived from experiments with artificially prepared membranes show

that parasitic fungi penetrate plant cuticle by purely mechanical means. By the use of a series of membranes of graded resistance the mechanical penetrating power of various fungi can be roughly compared.

Intact plant-surfaces which are not attacked by a given fungus are readily penetrated when the support of the underlying tissue is removed—*e.g.* when the tissue is killed by antiseptics or other agents, or when the supporting tissue is cut out. For this purpose it is not necessary, however, to kill the supporting tissue. Temporary reduction of turgor by plasmolysis is equally effective.

17. **Discussion** on *Vegetative Propagation.*

(*a*) Prof. J. H. Priestley.

For the perpetuation of many strains of cultivated flowering plants which are the product of long periods of selection and hybridisation, no method is available save that of vegetative propagation, and no practice is more commonly employed in horticulture. At the same time success or failure in vegetative propagation is a matter of experience, and generalisations as to the conditions for successful propagation are founded upon empiricism. A study of the process of vegetative propagation in the light of the development and anatomy of the flowering plant suggests that importance attaches to the following considerations :—

1. Roots and shoots differ in their mode of growth and in their nutrition under conditions of vegetative propagation ; they originate in different tissues and their production is differently affected by external conditions.

2. The production of new roots and shoots in a Monocotyledon is a very different problem from that presented by the Dicotyledon. In the latter the new growing points arise in close association with the two cylinders of secondary meristematic tissues, the vascular cambium and the cork phellogen.

It is suggested that no interpretation of vegetative propagation will prove practicable until a much wider knowledge is obtained of the processes governing the origin of meristematic tissue and its maintenance in healthy activity. From this standpoint the conditions governing the activity of the two cambial cylinders of the Dicotyledon are briefly examined.

(*b*) Prof. Neilson Jones.

(*c*) Dr. R. C. Knight.

(*d*) Dr. R. J. D. Graham.

(*e*) General Discussion.

18. Dr. Macgregor Skene and Miss G. L. Stuart.—*The Physiology of Sphagnum.*

The cause of the sensitiveness of Sphagnum to alkaline solutions has been investigated by a new method. By using carbonate-bicarbonate buffer solutions it is possible to vary the hydrogen-ion concentration and the concentration of salts independently, and to show that low values of the former and high values of the latter cause injury. Marked antagonism between different bases exists under certain conditions. No evidence was obtained of the dependence of healthy growth on a particular basic ratio.

19. Dr. B. Millard Griffiths.—*The British Freshwater Phytoplankton.*

The free-floating microflora (phytoplankton) of ninety-four English lowland waters has been examined. The phytoplankton considered as one of the communities of aquatic-plant association. Its habitat conditioned by initial water-supply, size of basin, local topography. The salts-abundance habitat ; its micro-, mero-, and holophotic variations and associated plankton types ; relation to corresponding salts-deficiency habitat. General habitat ranges of common species. Relation of British F.W. phytoplankton to that of other regions.

20. Mr. C. Leonard Huskins.—*Cytological and Genetical Studies of the Origin of Fatuoid Oats.*

A comparative cytological study of the microsporogenesis in fatuoids from various varieties of cultivated oats and in pure species of Avena has shown certain

chromosomal irregularities to be of very frequent occurrence in the fatuoids. Specific irregularities are also correlated with an unusual segregation ratio in one strain of heterozygous fatuoids. Extremely irregular cytological conditions are characteristic of the sterile dwarf fatuoids, which occur commonly in some strains and only occasionally in others. The combined genetical and cytological evidence obtained in these studies indicates that fatuoids owe their origin to chromosomal aberrations.

21. Miss C. Clint.—*The Life-history and Cytology of Sphacelaria Cirrhosa, var. Aegrophila.*

The paper deals with the relationship of Sphacelaria to its host-plant, *Halidrys siliquosa*, and traces the distribution of the former over a considerable area of coast, and its development throughout a twelve-month period.

The cytology has been worked out and the position of the reduction-division in the life-cycle established. Special attention has been paid to the nature and behaviour of the spores from two types of sporangia; sexuality has been definitely established in one of them.

Tuesday, August 10.

22. Miss S. H. Martin, Miss M. W. Rea, and Prof. J. Small.—*The Reaction of Plant Tissues.*

Method.—By using a series of indicators upon fresh-washed sections and noting colours rather than tints, the reaction may be placed definitely within one of a series of ranges.

Results.—A preliminary survey of 166 species, using in most cases the young flowering stem, shows: (1) that the tissue reactions vary in general between $P_H6.0$ and $P_H4.0$, and (2) that certain tissues, *e.g.* xylem and epidermis, tend to be more acid than others, *e.g.* cortex. Tendencies towards greater or lesser acidities are indicated in particular families or groups of families.

Detailed studies of the reaction of all tissues of the sunflower and the broad-bean, from the seed stage to anthesis, indicate that, while the reaction of some tissues remains constant, that of others varies with position above or below soil and with age.

The buffer action in the sap from the hypocotyl of the sunflower is shown to be due to a very dilute solution of inorganic phosphates.

Other results include the tissue reaction of selected stems for each month of the year and of the stems and leaves of a few species in a variety of habitats.

23. Miss Fry.—*The Penetration of Lichen Gonidia by Fungal Constituents, with special reference to Lecania candicans.*

24. Joint Discussion with Sections C (*q.v.*) and D on *The Conception of a Species.*

25. Joint Meeting with Sub-section K* (*q.v.*). Prof. J. W. Bews.—*The Ecological Evolution of Angiospermous Woody Plants.*

26. Dr. R. Kräusel.—*On New Devonian Plants.*

The flora of the Middle Devonian of Elberfeld consists of a series of plants, which are evidently from different sources. Some of them are autochthonous; they grew in rush-like clumps in a shallow coastal lagoon. On the other hand, water-transported remains of land-plants are also present.

Among the lagoon-plants occurs, first of all, a tall-growing *Asteroxylon, A. elberfeldense*, of which the upper, naked sporangiophores were first described as *Hostimella hostimensis*.[1]

[1] It appears, however, that the Bohemian Hostimellas belong rather to *Pseudosporochnus*. This genus is a true member of the Psilophytaceæ, for the supposed 'leaves' are nothing but the terminal sporangia. Some badly preserved fragments from Elberfeld may belong to *Pseudosporochnus*.

Further, we find an articulate plant, *Calamophyton primævum*, with triangular xylem, finely cut whorled leaves on the smaller branches, and lax, cone-like fructifications.

Similar fructifications also occur in *Hyenia elegans*, nearly related to the *H. sphenophylloides* of Nathorst, and, like that, without any clear nodal articulations. The two genera are regarded as representatives of two series, Hyeniales and Calamophytales, and are placed before the true Articulatæ, as Proto-articulatæ. Possibly another, hitherto undescribed, plant-form from Elberfeld may likewise belong here.

Hyenia may be regarded as a small, xerophytic shrub. The same applies to *Cladoxylon scoparium*, the first species of the group in which the foliage and sporophylls are now known. The systematic position of the Cladoxyleæ is still doubtful.

Finally, the last land-plant is of the habit of a tree-fern. But the ramifications of the large pinnæ show the anatomical structure of an axial organ—namely, a xylem-body consisting of reticulately pitted tracheides, with narrow medullary rays.

Only the nerveless ultimate pinnules can be interpreted as foliar organs. The sporangia of the fertile branch-systems may be considered as terminal. *Aneurophyton germanicum* stands near to *Eospermatopteris*, Goldring. Further forms belonging here are *Spiropteris*, *Sphenopteris condrasorum*, and *Cephalotheca mirabilis*. Whether we are dealing with primitive seed-plants is still an open question, as is also the conjectural near relation to *Palæopitys*.

The flora of Elberfeld has both geological and botanical significance. The Psilophytales, including *Asteroxylon*, render possible a connection of the microphyllous plants with the mosses. Forms like *Hornea* and *Anthoceros* stand near one another. They suggest the hypothesis that the leaf has here originated as an epidermal emergence. *Aneurophyton* also possesses leaves of that nature. On the other hand, the leaf of a true fern (and hence also, no doubt, of the seed-plants, except perhaps the Coniferæ) is to be compared with the whole pinnate branch-system of *Aneurophyton*.

The flora of the Middle Devonian already enables us to recognise at least two distinct developmental series for the higher plants. For the present it may remain undecided whether these series go back to a common stock. The flora consists of quite distinct, highly organised types, which are mingled with representatives of the Psilophytales. It shows similarities with the Middle Devonian flora of Scotland, Norway, and Bohemia.

26a. Prof. R. J. Harvey-Gibson, C.B.E., and Miss D. Milner-Brown. *Fertilisation in Bryophyta. Polytrichum commune.* (*Preliminary Note.*)

From the researches of Pfeffer, Buller, Lidfors, and others it has long been known that sperms are attracted to the archegonia of Pteridophyta by malic acid or other chemotactic substance, that sugar is the attractive body in Musci and a proteid in Hepaticæ, provided that the living sperms are brought into the vicinity of the open necks of the archegonia ; but, so far as we are aware, there is no record of how the sperms, in the first instance, reach the archegonia. As the result of prolonged observations on *Polytrichum commune* during spring and summer of the present year, we have established the following facts :—

(1) Both the male and the female ' heads ' are constantly visited by mites belonging to the group Oribatidæ, two species of ' spring tails ' (Collembola), a small midge (Diptera), a larval form of one of the ' leaf hoppers ' (Cicadidæ), an Aphis, both winged and apterous forms, and a spider. (For the identification of these insects, &c., we are indebted to Prof. R. Newstead, F.R.S., who has examined them *in situ*.)

(2) Contrary to our original expectation, we found that the paraphyses contained no sugar but mucilage only. The mucilage was abundantly exuded, especially from the spathulate paraphyses on the male ' head,' but also as well from the filiform paraphyses round the archegonia.

(3) The visiting insects greedily lap this mucilage, while at the same time their bodies, legs, mouth parts, and antennæ become smeared with the excretion. They also lick at the saline crystals formed on the perichaetial leaf-margins. They even pierce the antheridia themselves, for in some instances their intestines were found to be full of chlorophyll grains. The mucilage on their bodies contains large numbers of sperms, actively motile. In cases where the antheridial walls have been pierced, manifestly the apical dehiscing apparatus of the antheridium is unnecessary.

(4) Female 'heads' yielded the same insects, whose bodies and limbs were also smeared with mucilage in which sperms were abundant.

(5) The paraphyses surrounding the archegonia are well provided with mucilage in which sperms were frequently seen actively motile.

The mucilaginous contents of the paraphyses have obviously the primary function of keeping the antheridia and archegonia moist, and secondarily, through the mediation of insect visitors, of facilitating the transference of sperms from the male to the female 'heads,' often at a considerable distance from the male 'heads.' Further investigations are being made, not only on other Musci but also on Hepaticæ.

27. Lecture by Prof. Sir FREDERICK KEEBLE, F.R.S., on *Plant Integration.*

Wednesday, August 11.

28. Mr. M. A. H. TINCKER.—*The Effect of Length of Day upon the Growth and Internal Composition of some Economic Plants.*

The response in growth-habit of plants subjected to curtailed periods of daily illumination has been described previously. Data now available indicate that this treatment influences the composition of the tissues :—

Dactylis glomerata—Cocksfoot 'Late Indigenous.'—'10-Hr. days' prevent flowering, cause reductions in the total dry weight per plant, in the percentage fibre in leaf lamina and sheath ; higher percentages of ash, total nitrogen, and protein are found in the leaves of treated plants.

Phaseolus multiflorus—Runner bean.—'10-Hr. days' accelerate flower production and retard stem elongation. In the stem, whilst the percentage of dry matter is increased, that of fibre is reduced. Much starch, however, is present. The dry weight of the leaves and total dry weight of treated plants exceed that of the controls at six weeks. The roots of treated plants are 'tuberised' and contain much starch. The leaves and stems of treated plants contain more protein than do controls.

Helianthus tuberosus—Jerusalem artichoke.—'10-Hr. days' limit stem elongation but favour intense 'tuberisation.' The stems of treated plants contain much more fibre and ash, the leaves less protein, than do control plants. Treated plants accumulate most of their carbohydrate in tubers, controls (more elongated) in their less fibrous stems.

29. Prof. T. JOHNSON.—*On Dipteris conjugatoides, n.sp.*

One of the least likely fossils to expect in the Irish flora is a representative of the anomalous group of ferns—the *Dipteridinæ*—now confined to Malaya and Polynesia. *Dipteris*, represented by four species, has occupied an isolated position in the Polypods, and has also been regarded, with its incomplete more or less vertical annulus, as a member of the *Aspidieæ*. Fossil evidence, however, shows it to be the relic genus of a group which had an almost world-wide distribution, in the Jurassic more especially. Forms are recorded from Bohemia, not far from the locality in Moravia in which the allied anomalous group *Matoniaceæ* occurred at the same time—the Upper Cretaceous. But for fossil evidence *Dipteris* would still be regarded as an isolated Polypod. In *Camptopteris spiralis* Nath. and other forms the group possesses some of the most remarkable plants known.

As the generic name indicates, the stipe of *Dipteris* may fork at its distal end so that each prong carries one distinct half of the frond with its appropriate vascular supply. The bifurcated or dichotomously divided lamina is itself palmately or digitately lobed, the lobes being strap-shaped, ovate, &c., with entire or toothed margin. Two main vascular bundles enter the lamina, one to each half from the stalk, and these bundles themselves dichotomise five or six times in their passage through the frond. The veins come off at a fairly definite angle, take a characteristic curve, and may run side by side, more or less parallel to one another, in the same lobe. The leaf may be so much segmented and the lobes so narrow that only one main bundle runs through each lobe as a midrib. In such a case an isolated lobe would not readily be recognised as part of a *Dipteris* frond. The smaller veins form a more

or less rectangular Dicotyl-like network through a 'Phlebodium'-like arrangement, as in *D. quinquefurcata* (Baker) may occur. The sori are abundant, scattered, naked, as in *Polypodium*; sporangia with paraphyses and incomplete more or less vertical annulus. Seward and Miss Dale give a detailed account (recent and fossil) of the *Dipteridinæ* to date.

The Ballypalady specimen consists of an incomplete stalked frond. The stalk is 10 cm. long 1 mm. wide. The segments of the lamina are 7 cm. long, 1.5 cm. wide. The whole frond is 16-17 cm. long and 10-12 cm. wide. The bifurcation of the stalk at its distal end is clearly observable, accompanied by the passage, into the two halves of the lamina, of the vascular bundles. One half of the fossil frond is very incomplete, but the lobes or segments of the other half are clearly observable and show well the repeated forking of the veins. The fossil is a sterile 'impress' only, and there is only here and there a trace of the reticulum of smaller veins. Of the recent species of the genus the fossil comes nearest to *D. conjugata*, and seems to fit in between normal fronds of this species especially as figured by Kunze in Diels's article, and the abnormal form figured by Seward. This likeness is in keeping with one's expectation. The nearer the fossil is in time to the living form the closer the resemblance to be expected. Our fossil, small compared with the fine specimens in the 'Levinge' fern herbarium in this museum, may be named *Dipteris conjugatoides*. The *Dipteridinæ* are first recognisable in the Keuper (Uppermost Triassic), reach their maximum development in the Jurassic with world-wide distribution, excluding S. America, S. Africa, and (curiously) E. Indies, and, as Gothan points out, already show signs of waning in many forms in the Wealden (Lower Cretaceous). Thus *Hausmannia*, a member of the group, is represented by, mostly, small forms only. One Jurassic species of this genus is recorded from the Upper Oolite or Kimmeridge (?) of Sutherland. Gardner describes fragments of leaves from the Eocene beds of Bournemouth as *Podoloma polypodioides* and *P. affine*. Seward notes the close resemblance of the venation as figured by Gardner to that of the venation of a *Dipteris*. Gardner's Fig. 6, quoted by Seward as *D. polypodioides*, is most like *D. conjugata* in venation, &c., but is 'probably of a different (unnamed) species ?' according to Gardner. If, as seems so, Seward's reference of *Podoloma* to the Dipterids is correct, the Bournemouth plants lend support to the view that the Malay Dipterids occurred in Britain in the Tertiary as well as in Ireland, as indicated by the Ballypalady fossil.

The gap between the fossil Dipterids of the British Isles and the living forms of the East Indies is in part bridged by the fossil beds of Bohemia. Velenovsky discovered a fern in the Cretaceous of Bohemia in which he saw a likeness to *Platycerium biforme* Hook. Krasser in 1896 noted its resemblance to a Dipteris and named the fossil *Dipteriphyllum cretaceum* (Vel.) Krasser.

Through the kindness of Dr. F. Nemejc I have received photographic illustrations of the Velenovsky fossil. The agreement with the Irish fossil in all ascertainable features is so pronounced as to indicate more or less complete identity.

The beds in Bohemia which yield fossil Dipteris also contain the anomalous Dicotyledon *Dewalquea*, of which Irish forms from the Washing Bay core have been recorded. I have also found, but not previously recorded, this genus in the Ballypalady beds.

As *Dewalquea* and fossil *Dipteris* (e.g. *Dipteriphyllum*) are essentially Cretaceous in their latest forms as recorded from Bohemia, Belgium, America (*Dewalquea*), their presence in Ireland in the Tertiary is of added interest.

30. Prof. D. Ellis.—*The Reproductive Methods and the Internal Structure of the Sulphur Bacteria.*

The results are the outcome of the detailed study of *Thiophysa volutans*. Hitherto, with one exception, only reproduction by fission has been known for the organisms of this group. In *Thiophysa volutans*, under certain conditions of equilibrium, reproduction by *budding* (similar to yeast-budding) prevails for a limited period, the organism increasing enormously in point of numbers. Under certain other conditions *endospores* make their appearance, thus forming resistant reproductive cells.

The internal structure of *Thiophysa volutans* is discussed, including a consideration of the purple colouring matter, the sulphur globules, cytoplasm, &c.

SUB-SECTION K*.—FORESTRY

(For references to the publication elsewhere of communications entered in the following list of Transactions, see page 449.)

Thursday, August 5.

Following upon the Presidential Address and the paper by Dr. T. F. Chipp in Section K (*q.v.*) :—

Visit to the Department of Forestry to inspect the various sections of the Department.

1. **Address** by the Chairman of the Sub-section, the Rt. Hon. Lord Clinton.

2. Mr. A. C. Forbes.—*Some Critical Points in Forest Economy.*

In its widest sense forest economy may be regarded as a term defining a complex condition of affairs in connection with national forests which is beneficial to the community, but not necessarily bound up with financial problems or questions of direct profit or loss. In its narrowest sense, forest economy means the use of the smallest quantities of material or the least expenditure of money to produce a definite result. The wider aspects of forest economy involve State supervision or control, or, in other words, a forest policy, and this policy may have different effects, or require very different methods of treatment.

3. Mr. L. Chalk.—*An Anatomical Study of the Development of Secondary Wood of Frasienus Excelsior.*

Friday, August 6.

4. Mr. W. E. Hiley.—*The Financial Return from Scots Pine and Corsican Pine.*

5. Sir James Calder.—*Timber and some of the Ways it is Used.*

6. Mr. F. H. J. Jervoise.—*Underwood and its Uses.*

Divided into two classes : (1) underwood with oak standards, (2) underwood pure, mainly either ash and hazel mixed or pure, and often with a certain admixture of birch or chestnut pure, or oak pure.

In many parts of the country the industry is 'dead' for varying reasons. In other parts the industry varies according to the degree to which it has been fostered as an adjunct to agriculture and village industries.

In Sussex at the present time the utilisation of chestnut underwood is a thriving industry due to the great demand for chestnut fencing.

In Hampshire and other counties the utilisation of hazel underwood is capable of giving employment to many men in the villages, either in the first process of 'cutting down' or in the more skilled employment of 'working up.'

The present trade in the products of the industry is quite considerable, such as crate-rods, barrel-hoops, etc.

The wages to be earned are quite good in agricultural districts, and classes for hurdle-making are distinctly popular, especially among boys.

The financial aspect can be distinctly good for the same reasons that apply to other industries, besides serving the additional advantage that it gives employment to agricultural labour which is not required during the winter months.

7. Prof. Augustine Henry.—*The Swamp Cypresses of China and North America.*

A recent paper by Prof. A. Henry and Mrs. M. McIntyre (*Proc. R. Irish Acad.*, vol. 37, pp. 90-116) describes in great detail the swamp cypresses, *Glyptostrobus* of China and *Taxodium* of North America. These two genera were widely spread over the northern hemisphere throughout the Tertiary era, their fossil remains having been found as far north as Spitzbergen, Greenland, and Alaska. Their distribution at the present time is much restricted in area and practically confined to marshy sites, where the roots of the trees develop peculiar woody growths called 'knees,' which project above the soil and enable the roots to breathe when the ground is inundated. The Chinese species, *Glyptostrobus pensilis*, has died out in the wild state, and is known only in cultivation in two limited areas, around Canton and Foochow. Like Ginkoo, it has been preserved from extinction for superstitious reasons. The Chinese peasants plant it beside villages to bring luck to the family home, and amongst rice-fields to increase the crop.

The wood of both genera is valuable on account of its strength, fine grain, and remarkable durability under trying conditions of moisture. The trees, when grown in swampy ground liable to inundation by fresh water, yield a considerable volume of timber. The object of this paper is to point out the desirability of making plantations of *Taxodium* and *Glyptostrobus* in the warm temperate zone, on marshy land which has hitherto been unproductive.

8. Mr. R. Maclagan Gorrie.—*Irrigated Plantations of the Punjab.*

Recent canal developments in the Punjab have brought huge tracts of land under cultivation, and, as these were previously semi-desert waste, the increase in population is enormous. The economic needs of these new colonies demand a supply of wood for fuel and timber, and this is being met by the establishment of artificial forests dependent upon canal irrigation.

The type of work required in these irrigated plantations is very highly specialised, and the methods now in use are the result of nearly sixty years' experiment in Changa Manga, the oldest plantation of this type. The experience gained by the Punjab foresters should be of the greatest interest to all who are connected with the canal-development schemes now afoot in many of our colonies and other countries such as U.S.A., Soudan, Australia, and Mesopotamia, where the economic needs of new canal colonies will have to be faced.

Choice of site. Water requirements for forest plantations are different from those of cotton and farm crops, thus site should be adjoining a main canal, not on a small distributary channel. All parts of a plantation should be within economic radius for extraction by some form of tramway to railhead.

Irrigation. Area is divided into compartments, each forming a wait for watering. Standard method of work has been evolved in Changa Manga since 1866 by trenching at 10-ft. intervals along contour. Water is led into trenches through a series of parallel distributary channels. Usual supply of water is 10 cubic feet per second for each thousand acres during six summer months, equivalent to a depth of 3 feet of water on whole area.

Methods of stocking:

- (*a*) Sowing. Seed of shisham (*Dalbergia sissoo*) is sown along lip of trench, and germinates on soil kept damp by water in trench.
- (*b*) Root and shoot cuttings. Two-year-old plants are transplanted after being pruned down to a stumpy length of main root and stem. Shisham responds to this treatment with greatly increased growth.
- (*c*) Saltpetre soils. These form a serious problem in the Punjab, and can be cured by stocking with root and shoot cuttings of shisham.
- (*d*) Alternatives to trenching. Success has recently been attained by stocking with root and shoot cuttings land which had previously been levelled under a temporary cultivation lease. Area is divided off by ridges to form acre plots, each of which is flooded separately.
- (*e*) Restocking felled areas. Clear felling on a 20-year rotation leaves ground full of stumps, but acidity of humus makes trenching necessary.

Dangers. (*a*) Drought damage due to failure of canal-water is serious and takes years to obliterate. It can be met by undertaking only such an area as can be irrigated

with the supply guaranteed, and by organising details of lay-out and routine to give maximum use of water. (*b*) Fungus attack by *Fomes lucidus* is serious parasite on shisham and doubtful parasite on mulberry (Morus alba).

Sylvicultural work. Thinnings are carried out at 5, 11, and 16 years on a 20-year rotation, but the first crop should be cut earlier, owing to increased yield in subsequent crops.

Financial success. The working of Changa Manga for 1923-24 showed a profit of over 46 shillings per acre per annum, and the younger plantations should show even better results. Apart from the financial success of these forests, and the large number of people for whom they provide employment, they fulfil a felt want, and should prove a very valuable asset in the economic development of our great canal colonies.

9. Mr. Leslie S. Wood.—*The Business Aspect of Forestry.*

The importance of the study of the business side of forestry.

Unprofitable areas and their effect on public opinion.

The principles underlying business finance and their application to forestry.

The hindrance to progress due to an imperfect understanding of the financial question.

The error of the compound-interest theory.

The true expectation of profit.

The necessity of stocktaking and the method of calculation.

The percentage growth of timber and its relation to the current rate of interest.

10. Col. Gerard F. T. Leather.—*Estate Saw Mills.*

11. Mr. E. V. Laing.—*The Water Content of Tree Seedlings and Transplants.*

The species selected were Norway spruce, Sitka spruce, and European larch. Determinations were made for root and shoot separately and for total plant. The objects of the investigation were to observe (1) how variations in the water content occur throughout the year; (2) the period of highest water content; (3) the factors affecting water content. Considerable difficulty was experienced in finding the water content of the root on account of the adhering soil-particles, but a method was devised whereby as accurate a result as possible could be obtained by introducing the water content of the soil in the neighbourhood of the roots.

It was found that there is a period of low water content and an extended period of higher water content. The periods of high and low water contents both show fluctuations which in roots conform to fluctuations in soil-water or rainfall and in shoots to temperature. Root content is high in the early part of the year in the spruces and falls as the season advances. The reverse holds with the shoot. In the larch the curves for root and shoot tend to follow each other. As regards total water content in the early part of the year, the roots hold the higher percentage, but, as the season advances, the shoots hold the greater proportion. The increase in the content of shoot and plant of the spruces is later than in larch—May for the former, March for the latter. As between species total, larch has a higher water content than Sitka spruce, and Sitka spruce higher than Norway spruce. Sitka spruce further, particularly in the seedling stage, shows less total fluctuations than Norway spruce, although seedling Sitka spruce shows very great root variations.

The water content of the root is influenced by soil moisture or rainfall. High temperature and low soil-moisture cause a decrease in all parts of the plant. Shading generally increases water content. Seedlings have a higher water content than transplants, and the younger the plant the higher the percentage of moisture. The older the plant the less are the variations. Frost causes a marked fall. Norway spruce was found to recover its water content more rapidly than Sitka spruce.

12. Dr. A. S. Watt.—*The Ecological Approach to Silviculture.*

While it is important to have a ready means of computing the site value of existing woodlands, an immediate need in British forestry is the assessment with some degree of precision of land available for planting. Much of this land bears grassland and

heath, both of which plant communities comprise several types. A method of interpreting these types of grassland and heath in terms of tree growth is presented and illustrated from the vegetation of the South Downs and of Aberdeenshire.

Conflicting conclusions based on observations of the practice of heather burning, methods of sowing and of planting cannot be satisfactorily interpreted until we first know that we are dealing with the same type of plant community.

The study of a series of related habitat complexes affords a method of correlating the growth of trees and their accompanying vegetation with the progressively changing habitat factors. This method discovers for us the behaviour of different species of trees not only towards the master habitat factors but also towards each other and the animals and plants which may prove injurious. In this last case the varying relationships may suggest a method of attack on problems of pathology and artificial and natural means of control.

Saturday, August 7.

Excursion to Lord Parmoor's Beech Woods in the Chiltern Hills.

Sunday, August 8.

Joint excursion with Section K to Bagley Wood.

Monday, August 9.

13. Mr. W. R. Day.—*The Parasitism of Armillaria Mellea in relation to Conifers.*

14. Dr. M. Wilson.—*Control of Meria Laricis in the Nursery by Spraying.*

15. Mr. J. S. L. Waldie.—*Brunchorstia, Disease of Conifers.*

16. Mr. Thos. Thomson.—*Chirk Experimental Area.*

The objects of the area and its inception. Soil and situation. Lay-out and cost of establishment. Methods of planting, their cost and results. Height growth measurements of different species. Notes on some of the more advanced and more interesting plots. Insect pests and fungoid diseases. Value of the area for demonstrations, practical work for students and experiments in different silvicultural operations.

17. Mr. W. Dallimore.—*The Aesthetic Value of Trees.*

This paper will direct attention to the decorative value of trees as apart from any scientific or commercial interest they may possess. Special attention will be paid to trees for suburban and other small gardens, for it is felt that a great deal may be done towards beautifying villages and the outskirts of towns if residents are encouraged to plant suitable trees in their gardens. In this connection suggestions are put forward that municipal bodies might pay greater attention to the cultivation of collections of trees in the parks and gardens under their control, in order that residents may be able to study them and be able to select the most suitable kinds for their requirements. Street trees will receive attention, also trees for country roads, large gardens, parks and ornamental plantations.

Tuesday, August 10.

18. Mr. C. J. Chaplin.—*The Application of Timber Testing.*

An outline was given of the development of the modern methods of timber testing which deal with strength with relation to the natural characteristics and the condition of seasoning of the timber. Former methods of testing ignored the basic factors of

density, rate of growth, percentage summerwood and moisture content and produced results which, while having some application in problems of design, produced strength values which could be quite misleading, and become dangerous when published as general engineering tables on strength of timbers. Engineers or architects in using such tables were confronted with the possible alternatives of loss in efficiency or loss in economy in their designs.

The modern methods described are those originated at Madison, Wisconsin, and through the co-operation of Canada, India, and other parts of the Empire became an international code for obtaining comparable strength values of timber grown in the different countries.

The need for material with a complete history beginning in the forest was emphasised, and this was followed by a general outline of the procedure of tests, including collecting the material, preparing and sawing the logs, and testing the specimens.

It was pointed out that the tests are designed to determine the inherent fibre-strength with relation to the natural characteristics. The variable of moisture content is eliminated by first testing the timber green and again when dried to a uniform standard moisture content of 12 per cent. The comparison of the relative strength values of the different species indicates their values as mechanical timbers. It was explained that the results of these tests on clear material form the basis for the study of the influence of defects in structural sizes, leading to systematic grading.

Over 3,000 tests on clear material of home-grown timbers have been done since the work began in the Timber Research Laboratory in April of this year. No work on the influence of defects will be done until some time later, when the tests on the small clear specimens are well advanced. Tests on the comparative strengths of home-grown and imported pit-props are being carried on, and several minor investigations on the strength of manufactured articles are in progress.

The work already begun at the Forest Products Research Laboratory, Farnborough, Hants, will be continued, and extended when the laboratory is transferred to its permanent site at Princes Risborough.

19. Mr. S. T. C. Stillwell.—*The Seasoning of Timber.*

After a brief introduction the seasoning process was described under two headings, the first of which concerns the moisture in the wood itself, and the second the necessary factors external to the wood.

So far as the moisture in the wood is concerned, it was shown that the difficulty of seasoning is due to a shrinkage of the structure which takes place as certain of the moisture dries out, together with the fact that moisture does not move freely from point to point inside the timber itself.

To obviate this difficulty it is necessary, in seasoning a piece of timber, to limit the rate of evaporation from its surface to correspond approximately with the rate of moisture movement from the interior portions to the surface.

Exterior to the wood, three factors are involved. Firstly, heat, which is taken from the surrounding air, is necessary to evaporate the moisture in the wood. Secondly, the temperature and humidity condition of the surrounding air determines the rate at which evaporation from the wood surface takes place. Thirdly, a circulation is required to ensure continual replacement of air which has given up heat and taken up moisture in drying the wood, so that the process may proceed continuously.

In considering the application of these factors in practice, it was shown that in air-seasoning conditions, the temperature and humidity of the air is variable and uncontrolled. The rate of drying, therefore, can only be regulated in a rough fashion by means of sheltering and other expedients. In temperate climates, however, the rate of drying is at most comparatively slow, and it is on this account rather than from precision of control, that serious damage is avoided. The necessity for circulation influences the form of pile, and not only is it necessary to build the boards with transverse sticks between each layer, but it is best to limit the width of the pile in the direction in which the air travels. It is also good practice to raise the pile well above ground level, and to provide good ventilation of the space below it.

In kiln-seasoning, the same factors and conditions enter into the drying process. At the higher temperatures of the kiln the internal moisture movement is more rapid, but the surrounding air has relatively greater evaporative powers, so the necessity for control is greater.

Kilns, therefore, are provided with means for temperature and humidity control. The latter is most important; poor control of humidity is responsible for most of the defects found in kiln-dried timber. Good humidity control gives kiln-seasoning its chief advantage over air-seasoning.

In all kilns some means intended to cause a movement of air through the piled timber is provided. Separation of the layers of a kiln pile is the invariable practice and, except in certain special kilns, it is necessary that the width of the pile should not be too great, otherwise the drying at the side by which the air leaves may be too slow for efficient working.

Thus, in kiln-seasoning, provision is made for the control of the important factors. Such control, however, is essential, and if it is inefficient the danger of damage to the timber is greater than occurs in air-seasoning.

But under the best conditions, not only does kiln-seasoning yield the highest quality of material, but on account of the control it is possible to adjust the final moisture content of the seasoned timber uniformly to the value suitable for any particular purpose.

The importance of precision in the final moisture content of the timber used in certain manufactures is probably chiefly responsible for the present development of kiln-seasoning.

20. Mr. J. F. Martley.—*Moisture Movement in Wood.*

A series of experiments was described on the passage of moisture through cylinders of Scots pine heartwood.

The effect on the rate of moisture flow due to altering the vapour pressure difference at the opposite faces and of varying the cylinder length was investigated. In addition the moisture gradients were examined, and the variation of the diffusivity of moisture in wood with the moisture content determined.

It was found that the rate of flow through the cylinders was proportional to the vapour pressure difference between the two faces and also when allowance was made for the existence of a surface resistance that the rate of moisture flow was inversely proportional to the length of the cylinder, other factors being constant.

The form taken by the moisture gradients showed that the diffusivity of moisture in wood was about six times as great near the fibre saturation point as when dry.

The conclusion drawn from these experiments was that if the law of diffusion was to be applied to the movement of moisture in wood, it would have to be modified by the inclusion of a term embodying the variation of the diffusivity with the moisture content.

The general differential equation of the modified law of diffusion would take the form :—

$$\frac{\delta u}{\delta f} = \frac{\delta}{\delta x}\left(f(u)\frac{\delta u}{\delta x}\right)$$

where $f(u)$ gives the variation of the diffusivity with the moisture content.

For the purpose of comparison with a non-colloidal substance, a similar series of experiments was carried out with plaster of Paris. Similar results were obtained as with Scots pine, with the exception that there did not appear to be a variation of the diffusivity with the moisture content, but it was not possible to decide this point definitely as the moisture gradient in the cylinders was not determined.

In conclusion, the bearing of the results obtained on the practical problem of kiln-seasoning was discussed.

21. Mr. Alex. Howard.—*A Country without Trees.*

22. Joint Meeting with Section K. Prof. J. W. Bews.—*The Ecological Evolution of Angiospermous Woody Plants.*

The evidence from fossil botany, though incomplete and unsatisfactory in many ways, lends strong support to the view that the moist tropical flora was at one time more widespread. Without relying on the supposed determinations of fossil leaf impressions, it is possible, by adopting statistical methods, to compare the fossil Angiosperm flora with modern types of vegetation. Comparisons of such features as leaf-size, leaf-shape, leaf-texture, leaf-margins, and the characters of the wood, show that the fossil Angiosperms from all over the world are ecologically most nearly

related to the forms at present occurring in moist tropical regions. The fossil evidence, however, is not relied on as the main line of attack on the problem of ecological evolution. The detailed evidence from phylogeny is much more convincing. Though general and somewhat speculative schemes of phylogeny for the Angiosperms as a group help but little, yet if attention is directed to the narrower circles of affinity (the well-defined orders, families, and larger genera), all the evidence supports the following conclusions regarding the ecological history of the flowering plants. Within the moist tropics, owing to the great lapse of time and the continued influence of the organic environment or biota, and to a much less extent minor changes of climate, differentiation has resulted in the production of a very large number of trees belonging to a great many separate, usually rather primitive, families, but of a fairly uniform ecological type, with evergreen, somewhat leathery, rather large, usually simple leaves, tall slender sparingly branched stems, often supported by buttresses, thin bark, and hard wood. They show no response to a resting period, and floristically are older than allied derivative types found in colder and drier regions. There have also been produced in the moist tropics large numbers of woody lianes, which connect with the more advanced herbaceous climbers, epiphytes which often connect with the lianes, and hygrophilous undershrubs and herbs. Many terrestrial forest margin herbs, according to recent investigations by Goebel, have velamen on their roots, and this may point to an epiphytic ancestry. All the subordinate tropical types are floristically relatively advanced.

In the drier sub-tropics (regions with dry winter resting seasons), in still drier semi-desert or desert regions, no one who is well acquainted with the flora can fail to be impressed by the fact that phylogenetically each of the types of plant represented is more recent than the nearly allied moist tropical types. The evolutionary trends are varied, the deciduous habit is usually adopted, the stems are shorter and often stouter, and there is an increase of branching, a decrease of size, their woods are generally softer, and features like thick bark, thorn development, and succulence are common. In general there are responses to the resting season with increased storage of food, and an increase of xerophytism. The warm temperate sclerophyllous woody vegetation of regions with wet winters and dry summers, though derivative, is not always so nearly related floristically to the moist tropical. A mountain origin for this type, probably at least as early as the Cretaceous period, is indicated by various facts, and in this connection it may be recalled that, while most of the great mountain ranges of the present time do not go back as far as the Cretaceous, those of the African continent are as old as the Permian. In this type responses to a resting period are not so well marked. The evergreen habit is retained, but there is a general increase of xerophytism. Hard leaves and deep root systems are general. The ericoid habit has been adopted by a very large number belonging to widely separated circles of affinity. The cold temperate woody plants are very few in number as compared with the others, and the genera are not large. The deciduous types connect with the sub-tropical, their fossil ancestors, where known, were for the most part apparently evergreen ; in regions such as S.E. Asia and Japan, where the record was not interfered with by the Great Ice period, the transitions are gradual. The cold temperate evergreen shrubs, including the heathers, connect rather with the warm temperate sclerophyllous and mountain types of the tropics. In studies on experimental morphology, where plant structure is correlated with the basic physiological processes, it seems advisable to pay some attention to phylogenetic history.

SECTION L.—EDUCATION.

(For references to the publication elsewhere of communications entered in the following list of Transactions, see page 449.)

Thursday, August 5.

1. Dr. Charles Singer.—*The Place of History of Science in Education.*

Historical teaching in science may be considered (*a*) in general education and (*b*) in the education of the scientific specialist. It is (*a*) that is here discussed.

Sciences are usually taught as systems of absolute knowledge, capable of extension but hardly of correction. This gives a false impression of how the scientific standpoint has been reached. Scientific knowledge is the product of generations of growth along

particular lines. If the lines of growth had differed the product would have been different. Social, political, religious, and psychological environment have all had their share in shaping the growth of scientific knowledge. Our Science is thus as much a product of tradition as our Law, and can only adequately be grasped by those who receive the tradition.

A radical and effective remedy would be a re-casting of the 'humane' side of school studies so as to provide organised instruction in the history of the things that 'make life worth living,' in other words of 'Civilisation.' The *History of Civilisation*, which includes the *History of Science*, could well become the basic humane study. The old classical education was really an attempt at imparting a conception of the History of Civilisation. The re-casting of humane studies is, however, too ambitious a programme.

There is a current idea that science has so 'advanced' that no one can survey it as a whole. If this were so, it would be reason to exclude science from general education, for if science does not unify and simplify it is of little educational worth. Some attempt must then be made to survey science as a whole. This can be done through history. The History of Science can be treated as a part of the History of Civilisation, which should replace the merely political so-called 'World History' or 'European History.' Science is here of special value because of the unifying impression given by it. Such a History of Civilisation would involve an elementary survey of science as a whole.

In expressing this attitude to scientific knowledge there is danger of misunderstanding. Science as such must involve contact with phenomena and not mere discourse. Teachers rightly fear the treatment of mere book-learning as though it were science. So far as the History of Science is concerned, however, the fear is groundless. It arises from a confusion of two separate functions of the teacher. On the one hand he has to train his pupil to live his life, on the other to provide him with a life worth living. Practical acquaintance with the method of science is necessary for the former. A general survey of science that would help him to understand his world is no less necessary for the latter.

2. Dr. R. T. Gunther.—*The Educational Value of the Lewis Evans Collection of Historic Scientific Instruments.*

The collection recently presented to the University of Oxford by Dr. Lewis Evans has been installed in the Old Ashmolean Building, erected in 1679-83, as a central Institution for Scientific Studies. It was evident that this collection, though especially rich in early astronomical and mathematical apparatus, would, from the very fact of its association with an historic building, serve as a lodestone round which would gather other collections illustrative of the history of scientific studies in Oxford. This expectation has been amply justified and students can now examine side by side several series of instruments illustrating the educational methods of the principal periods of European science.

Starting with astrolabes made by Moors in Spain in the eleventh and twelfth centuries, we have instruments used in Oxford by the members of the Merton School in the fourteenth century, one of these, the rectangulus of Richard of Wallingford (1326), has been reconstructed for the first time this year, its sixth centenary. The navigational instruments of the Elizabethan period are well represented by the great astrolabe of Humphrey Cole, specially lent, with other instruments, by the University of St. Andrews for exhibition at the meeting. The earliest known theodolite by the same eminent maker is also shown. The scientific inventions of the founders of the Royal Society in Oxford can, unhappily, only be illustrated by a few models and reconstructions of works by Boyle, Hooke, Wren, and Mayow, but the period immediately following is most admirably illustrated by the unique orrery collection, lent by Christ Church, and the nature of the scientific teaching of a century later, 1790-1820, is shown by the cabinet of physical apparatus lent by Oriel College, and by some old chemical glass from the University laboratory in the Old Ashmolean Building. This, perhaps the oldest collection of chemical glass in the world, illustrates educational methods from the time of Lavoisier to that of Sir Humphry Davy. We owe its preservation to one of the founders of the British Association, Dr. Charles Daubeny, and to his successors at Magdalen College.

Suggestions as to the best method of displaying these historic treasures are invited by the Curator. At present they are all on exhibition in the Old Ashmolean Building.

3. Prof. C. H. Desch, F.R.S.—*The History of Science as a Link between the Sciences and Humanities.*

It is not advisable that separate classes in the history of science should be introduced into the courses of instruction for students, whether pass or honours, although special courses may well be provided at a few selected centres. For the ordinary student of science instruction in the history of his subject is best given as a part of the normal course, the historical order of development being adopted by the teacher in his introduction, whilst the higher portions are illustrated by biographical matter and by the reading of original memoirs. By relating each important discovery as it is dealt with to the state of thought at the time, the importance of science in human history may be made clear. In the teaching of applied science, the connection between great discoveries and inventions and social and economic conditions affords many themes for an enthusiastic teacher, and furnishes a means of directing the attention of the student to social studies, which are so apt to be neglected by the scientific specialist. On the other hand, the student of history and literature may be brought into contact with the facts and conceptions of science by a similar approach. The link can only be completed by the recognition of sociology as a science, and this recognition is maintained to be the only true means of bridging the gulf between the sciences and the humanities which is too characteristic of modern education.

4. Prof. D'Arcy Thompson, C.B., F.R.S.—*Schoolboy Science.*

5. Visit to the Lewis Evans Collection at the Old Ashmolean Building.

6. Joint Discussion with Section M on *Educational Training for Overseas Life* in the hall of the Union Society.

Sir Thomas Holland, F.R.S.; Sir A. Daniel Hall; Hon. W. Ormsby-Gore, M.P.; Miss Gladys Pott; Sir Alfred Yarrow, F.R.S.; Sir John Russell, F.R.S.; Mr. T. S. Dymond; Mr. G. W. Olive; Mr. H. W. Cousins.

(See Report *in extenso*, p. 450.)

Friday, August 6.

7. Presidential Address by Sir Thomas Holland, K.C.I.E., K.C.S.I., F.R.S. (See p. 246.)

8. Discussion on *Scholarships.*

(*a*) Mr. William Hamilton Fyfe.—*Methods of Selections, and Influence on Present System of Education.*

The function of a University is to assist the development of those who have the capacity for mental growth.

Ideally all other candidates would be excluded, and those who seem to have the capacity would be admitted regardless of their means.

At present, tests are needed to assure the presence of this capacity in those who receive financial aid. 'Intelligence tests' are at present inadequate for this purpose. The only existing method is that of the scholarship examination.

This shares the educational disadvantages common to all written examinations, which demand the appearance, not the reality, of knowledge, encourage reproduction instead of original effort, rate acquisitiveness above the faculty of enquiry, and belittle the value of the individual search for truth.

It is important to devise—or at least to proclaim the need for—some test less hostile to the objects of education.

A disadvantage peculiar to these scholarship examinations is their specialised nature, which requires a boy to narrow his curriculum before he has acquired a good

general education. The 'two-or-three-subject boy' is likely in the long run to go farther than the specialist.

An objection in detail to the present conduct of scholarship examinations is that at the University of Cambridge the great majority of college scholarship examinations are held in one week.

(*b*) Miss J. P. Strachey.—*Scholarships at Women's Colleges.*

(1) At Oxford the women's colleges give the status and title of scholar and exhibitioner on merit alone, and award emoluments, if any, according to need. In this they are conforming to the provisions of the new Scholarship Statutes of the men's colleges. At Cambridge the earlier practice of awarding scholarships of definite amounts still prevails in the women's colleges. A certain number of these scholarships, such as the Mary Ewart of £100 at Newnham and the Carlisle Scholarships of £100 and £80 at Girton, carry a poverty qualification.

(2) The figures available for the Oxford colleges are not easy to analyse because examinations are held twice a year, in December and March, and there is no information as to how many candidates present themselves twice. It seems, however, as though at Oxford English, History and Modern Languages attract the largest number of candidates, in that order. The number of candidates in Mathematics and Science is small.

At Cambridge the numbers have risen steadily since 1921, when the first Girton and Newnham Joint Examination was held. History, Mathematics and Science have the largest numbers of candidates, History having this year ousted Mathematics from the first place.

(3) In the list of schools from which scholarships or exhibitions were won in both Universities there were in 1921 three County Secondary or Municipal Schools; in 1926 this number had risen to nine. The rise has been steady except for a slight setback in 1924. But probably these figures should be corrected by a closer analysis of the types of schools and the inclusion of those which are called 'High Schools,' but which are of recent foundation and under local authorities.

(*c*) Mr. S. How.—*Preparatory Schools and Scholarships.*

The need for scholarships. Different types of Preparatory Schools. Advantages to scholars other than financial. Method of selection. Varying conditions. Effect on candidates. Effect on curriculum of Preparatory Schools. Possible improvements in the system.

(*d*) Mr. J. L. Holland.—*Elementary Schools and Scholarships.*

9. **Discussion** on *The Cinema in Education.*

(*a*) Dr. C. W. Kimmins.—*The Educational Possibilities of the Cinema and the Wireless.*

The findings of the Cinema Commission and an investigation of the type of film preferred by children at different ages. The Report of the Research Committee on the educational value of the cinema. Experiments on visual instruction carried on by the Board of Education in New York. The comparative failure of the present educational film. Suggestions for an improved type of film for educational purposes.

(*b*) Mr. G. T. Hankin.—*The Use of Films in Schools.*

Educational opinion on the value of the cinema is gradually changing. A growing desire to utilise its powers can be noticed in many types of schools. Two recent experiments in this country deserve specially detailed consideration. The first, under the control of a committee of the National Council of Public Morals—of which Professor Spearman was chairman, and Prof. Burt secretary, was conducted under test conditions by Mr. Philpott for a period of two years, and elucidated with some accuracy the value of the cinema as a teaching instrument. The second has been carried out this year on some thousands of school children by means of a film on the League of Nations, produced by the League of Nations Union. The answers of one hundred and fifty teachers to a detailed questionnaire show that, with the aid of teaching notes, the original master and mistress can make real use of a film. It

provides a nucleus of interest otherwise unobtainable ; but preparatory and follow-up lessons, the latter of a special type, are necessary. The production of educational films is still almost negligible in this country. Producers cannot afford to produce educational films to meet the very small demand, and education authorities cannot be expected to install projectors until a supply of educational films is secured. Further experiment and demonstration are necessary to rouse enthusiasm among teachers, from whom the demand must ultimately come.

10. **Discussion** on *Wireless in Education.*

Mr. J. C. Stobart.—*Education by Wireless.*

The B.B.C. was formed in 1922 as an entertainment body only, but immediately began to develop along three specific lines—entertainment, information and educational instruction. Its responsibility was recognised very early, and steps were taken to form in each centre where the B.B.C. had stations educational advisory committees composed of leading local educationists, whose advice and co-operation was invited.

A further step forward was taken in 1924, when a successful demonstration was given before the Board of Education. Shortly afterwards this department lent one of H.M. inspectors of schools to act as Director of Education. A series of experiments in method and technique were instituted. General culture, adult education and school transmissions were the three main lines of development.

It is now claimed that the experimental stage has been satisfactorily concluded, though better organisation of reception is required before complete satisfaction can be felt with the service. This can only be obtained by definite effort on the part of the listener in discarding inferior apparatus and in following up wireless instruction by systematic courses of reading. There are, however, an immense number of adults following with interest the evening courses of lectures and many hundreds of teachers who regularly use wireless in their school programmes. Co-operation with universities has been secured at all stations.

Up till now technical difficulties have restricted the scope of educational broadcasting, but with the institution of an alternative wave-length system, soon expected, it should be possible to make considerable further progress, since the present need of reconciling instruction with entertainment in one programme will then be obviated.

The next step forward should be the formation of listening classes, possibly in connection with the rural libraries scheme. Negotiations are already in train to this end. Local education authorities are realising more and more fully the assistance which wireless can give towards solving the problems of rural education, and though financial stringency is still the chief obstacle, the number of pioneer schools continually increases. Official adoption cannot be long delayed.

Saturday, August 7.

Excursion to Chedworth.

Monday, August 9.

11. **Discussion** on *Recent Advances in Educational Science.*

(*a*) Prof. T. P. Nunn.—*General Conceptions and Scope of Education.*

Developments in the general conceptions and scope of education during the last twenty-five years are related partly to advances in psychology and philosophy, but more fundamentally to changes in national consciousness and attitude greatly accelerated by the war. Before the war the public organisation of education looked mainly towards increasing national efficiency or consolidation ; since the war these ideas have been supplemented and largely replaced by the idea that education should aim universally at the maximum development of the individual citizen. The educational movements now in progress in the greater nations are to be interpreted chiefly in relation to this profoundly important change of emphasis.

(b) Miss MARGARET DRUMMOND.—*The Education of Children under 11 years of age.*

General principle. Content and method of education must be determined by interests and capacities of child.

Period to be considered falls naturally into three parts, each of which is marked by different interests and capacities, viz. : (*a*) pre-school or nursery period up to five years of age ; (*b*) 'infant' period, 5-7 ; (*c*) junior period, 7-11. The first of these is the most important, as then foundations are being laid and attitudes established which, to a large extent, determine the future.

During the first two or two and a-half years education is strictly individual and is given in the home. In the latter half of the nursery period, the child benefits by being one of a group. Sense training. Language and number interests. Principle of freedom.

Period of 5-7. Differences in mental age. Dangers of class instruction. Individual work the only psychologically sound method. Exceptions. Language study should be so directed as to lay the foundations for all the sciences.

Period of 7–11. Principle of continuity. Gradual introduction of drill, *e.g.* in number combinations. Competition as a stimulus. Value of group lessons in literature. Spelling. Introduction of a second language.

During these early years the foundations of physical health should be laid. Much play in the open air essential. The time table should be subservient to the sun. Our great need is to distinguish between what in this period comes through growth and what comes through teaching. It is practically certain that at present we overteach, and we overestimate the value of schoolroom activities.

(c) Dr. M. W. KEATINGE.—*Developments in Methods of Teaching.*

Can method be defined ? Preliminary description. Brief sketch of its history up to the end of last century in (1) elementary, (2) secondary education.

New factors introduced by (*a*) experimental science, (*b*) a new social outlook, (*c*) a new psychological standpoint. Consequent extreme complexity of the problem leading to a consideration of such factors as the following :— Class teaching ; individual work ; the relation between the two ; laboratory methods ; the period of the year ; and of the term ; fixed syllabuses ; the relation between routine work and special lessons ; examinations ; the age of the pupil. The essentials of a method that can deal with these situations and factors.

(d) Prof. J. STRONG.—*The Organisation of Education.*

The growth and development of educational organisation in this country has been more or less haphazard ; hence, among other things, the lack of articulation of its parts, the variety of nomenclature of its schools, and not least, the absence of definition of its terms. These have their disadvantages ; they also have their compensations. Looseness of organisation lends itself more readily to changes and modifications, and lack of definition to the encouragement of experiments. No one imagines that the organisation of education in this country has reached the stage of perfection. The problem is, as always, to find the line of true development.

Education immediately beyond the primary stage still awaits organisation. To some extent it would be simplified by giving to secondary education a wider and more comprehensive meaning ; it should be less a question of subjects and school equipment than of abilities. The relation between technical colleges, training colleges, and the university still has to be defined. The desire of these colleges to-day for closer connection with the university points to the need for a simpler organisation. The influence upon educational organisation of an extended administrative system, central and local, cannot be overlooked.

(e) Prof. CYRIL BURT.—*Educational Psychology.*

I. *The Psychology of Teaching Methods.*

A. The general study of learning, memorisation, mental work, mental fatigue, as it affects the classroom.

B. The experimental pedagogy of special subjects of the school curriculum.

II. *The Psychology of the Individual Child.*

A. The measurement of intelligence; the standardisation of mental and scholastic tests; the study of the subnormal (including the dull, the backward, the mentally defective); the study of the subnormal (including the selection of scholarship candidates).

B. The analysis of temperament and character; the diagnosis and treatment of the neurotic child and of the juvenile delinquent.

Tuesday, August 10.

12. Discussion on *The Public School System.*

(*a*) Mr. Ronald Gurner.—*The Public Schools and National Life.*

(1) Difficulty of generalising about public schools. No definition—boarding or day school, school for one class only, school that does not take grants—entirely suits.

Suggested definition—non-local school, usually with tradition, independent of local authority.

(2) Rough description of or allusion to public school system in these schools.

(3) Various lines of criticism on such a system :—

(*a*) Premium on brawn, not intellect.

(*b*) Crushing of personality.

(*c*) Not 'public school'—ex-elementary scholar excluded. (Labour line of argument.)

(4) Examination of these criticisms. Public schools have carried on in spite of them, and are successful till to-day.

(5) Why? Value of public school qualities, honour, *esprit de corps*, etc. (Mr. Cyril Norwood's defence of public schools.)

Public school system doomed if interpreted in wrong sense—exclusiveness; greatest national asset if interpreted in right sense—spirit of service. What will be the public schools' interpretation of their own system in the future?

(*b*) Mr. M. L. Jacks.—*A Training in Community Life.*

1. It is only possible to learn how to do a thing by doing it. Education, therefore, which should aim at the production of citizens rather than scholars (though the scholarly type of mind is an essential element in good citizenship), ought to provide an opportunity of living a community life modelled on the life of the larger community.

2. Some of the requirements of good citizenship in a community are these :—

(*a*) Co-operative work for an end beyond self, and a sense of responsibility towards the whole.

(*b*) Ability, among men good and bad, to choose the good and to live with them, and to deal adequately with circumstances good and bad.

(*c*) A type of mind accurate enough and sensitive enough to the truth to be able to discern the true meanings of things, the true facts of a case (as distinct from the inferences), the true characters of people, and not to be misled by the hazy kind of idea which can find convincing expression in a newspaper headline, or the rhetoric of politics.

(*d*) Power to strike a happy mean between a natural and right desire for the expression of a personality possessing something of unique value for the community, and the facts of a life which tend to inhibit that expression.

(*e*) A recognition that all work, whatever its nature, which is done honestly and thoroughly is honourable. 'All true work is religion' (Carlyle).

3. Public schools provide a very workable copy of a community which makes such demands.

(*a*) They lay the emphasis on living a life, and not learning a lesson, and on the responsibility of each to all.

(*b*) They throw together into very close contact individuals of varying degrees of moral worth and strength, and each individual is left to make his choice of friends. Some of the circumstances reproduce those of the outside world.

(*c*) The curriculum does much to produce the desired accuracy of mind.
(*d*) Personal idiosyncrasies are perhaps more harshly repressed than they are even by conditions of modern life.
(*e*) While there is no emphasis on bread-and-butter subjects, it is perhaps doubtful whether the gospel of work for work's sake, whatever its nature, is sufficiently grasped.

4. Thus we have a community, perhaps sometimes out of touch with the real thing, but a useful copy of the real thing, where the practice of life may be learnt by living.

5. (*a*) The old idea of education was pouring something into an empty vessel.
(*b*) The most up-to-date idea is drawing something out of an apparently empty vessel.
(*c*) The idea here put forward is that of the public schools; it is that all education is life, and all life education.

(*c*) Dr. Crichton Miller.—*Essential and Extrinsic Features of the Public School System.*

(A) Essential features: (1) Boarding school,
(2) For one sex,
(3) During adolescence.

Therefore exclude day schools, co-educational schools, and preparatory schools.

(B) Extrinsic features:
(1) Close connection with the older universities.
(2) Predominatingly classical education.
(3) Strong emphasis on athletics.
(4) Prefectorial system.
(5) Corporal punishment.

Broadening tendency in all directions.
Psychological justification for A (1) and (2).
The uniqueness and value of the prefectorial system.
The significance of corporal punishment.
The success and failure of a standardising or levelling machine.
Applicability to average cases and inapplicability to special cases.

(*d*) Mr. F. J. R. Hendy.—*A Critical Appreciation.*

Almost all commonly urged in favour of the public schools can be accepted—their great tradition; the effect on the character of their members of the inspiring buildings made possible by their great resources; the high character of the public school master; their non-local character, which collects together boys from all parts and widely different environments; and the strong corporate sense coming from common life. The public school is essentially the school to produce public servants and rulers of an empire.

Against this are to be set these disadvantages:—(1) boarding school life separates the boy from his family and from feminine society, deprives the parent of the liberalising experience of rearing his own sons and places on the schoolmaster too heavy a burden. (2) The public schools cater for a class—and a wealthy class. (3) They have no local monopoly, like the day schools, and have to compete for numbers. (4) They produce 'good fellows' of high quality but without great intellectual attainment. (5) Above all, they have produced a severance in English education, and caused an unequal distribution of the human and material resources available for education. If the more truly national system of local secondary education could participate in the endowments and have a share of the boys and masters that go to the public schools, the national gain would be great.

In spite of all, the public school system is invaluable to the nation, and will last as long as our social system lasts. It has supplied a large proportion of the head-masters and inspectors and administrators of other types of education in Britain and the Empire. These are spreading the principles of the public school system into the local secondary and elementary schools and the hope is that these will ultimately develop into 'public schools without the dormitories.'

(*e*) Mr. W. W. Vaughan.

Many of the misconceptions in the public mind arise from those who write novels about the public schools, because they find themselves unable to make a living in any other way. These critics know nothing of the modern public school and never by any chance mention the musical and scientific societies or that great institution, the O.T.C. So far from wishing to keep the public school spirit to themselves, public school men desire nothing better than to extend it into every school and every section of the community. They are sometimes told that they want to shut out the parent. On the contrary they welcome the parents' co-operation.

SECTION M.—AGRICULTURE.

(For references to the publication elsewhere of communications entered in the following list of Transactions, see page 449.)

Thursday, August 5.

1. Mr. J. A. Venn.—*The Yields of British Crops; an inquiry into the results attaching to past and present methods of crop estimating and forecasting.*

In 1868 Lawes and Gilbert prepared the first estimates of wheat yields to cover a series of years; these commenced with 1852 and recorded a figure for the United Kingdom of 28¼ bushels, which unfavourable seasons subsequently reduced to less than 25 bushels during the 'seventies. Official statistics, inaugurated in 1884, indicate a slow advance up to about 1910, when a level of 32 bushels was attained. Since then there has been a loss of a bushel. These movements cannot be correlated with the area under the plough or under wheat, are in the main applicable to other cereals, but are little evidenced in Scotland and Ireland, where all such yields are in excess of the English level.

Concurrently with the introduction of the official series, deviations from the normal became less marked; thus the Rothamsted figures had shown a mean range equivalent to 14 per cent., while the official series at first indicated a deviation of 7 per cent., which has steadily declined to the present level of below 5 per cent. Comparison with other countries producing cereals under similar conditions affords widely divergent results, *e.g.* in Denmark the figure is 13 per cent. and in Germany 10 per cent. The Rothamsted estimates were merged into an annual statement published by *The Times*. Close comparison of these figures (prepared locally by a large body of experienced agriculturists) with the official series indicates that in almost 80 per cent. of instances they exceed the latter by substantial margins. Investigation of the statistical methods respectively employed fails to account for this divergence. Further, the official figures display chronological and geographical inconsistencies; thus, although half the wheat produced in the Eastern Counties has recently been shown to consist of the newer varieties, there is no indication, officially, of increased yields from this area.

These results appear to be due to conservatism on the part of Crop Reporters, and are in no way attributable to the methods of amalgamation and weighting adopted by the Ministry of Agriculture, whose statistical work is unassailable. Local under-estimation of, perhaps, 5 to 10 per cent. in the case of cereals and 15 to 20 per cent. in that of roots seems, however, to be operative.

In common with those relating to other countries, official crop forecasts also show a pessimistic trend, for, if the series issued at monthly intervals prior to harvest is closely compared with the actual estimates of yields subsequently recorded, it emerges that there is a tendency (*a*) seriously to understate the position, and (*b*) not to anticipate an above-average crop. Forecasts issued by *The Times* are free from this bias.

The institution of 'Standard plots,' together with possibly the reorganisation of the part-time personnel of the Ministry, might ameliorate both of the above tendencies, viz., to forecast sub-normal crops and to understate actual yields.

2. **Discussion** on *Cultivation Methods.*

Prof. J. A. S. Watson, Mr. W. J. Malden, Mr. J. R. Bond, Dr. B. A. Keen, Mr. Newman.

One of the most striking facts about tillage is that we of to-day know little more of the essential principles than has been known for centuries. To a limited extent science is able to explain, in terms of colloids, surface action and so on, facts that have been a matter of common experience to countless generations of farmers—that land which is ploughed too wet will dry into hard clods ; that these clods can be most readily crumbled after frost, or after they have been dried and again moistened, or that moisture will rise in a fine and firm tilth. Science, too, has shown that the physical condition of the soil can be influenced by the addition of chemical flocculents, but in the main we still rely, like our forefathers, on frost and drought and rain to produce the results that we desire, and when these fail us we must resort, as they did, to main force, exerted through crude and clumsy implements.

Such improvements as have been made in these implements have been arrived at by purely empirical methods, without any fundamental knowledge of the problems involved. A large amount of research in soil physics will have to be carried out before we can state the problems of tillage in terms that our engineers can understand. In the meantime we have the rather urgent practical problem before us of cheapening and improving our processes.

In this country, with its particular circumstances of soil and climate, the cultivator's immediate object may be to produce any one of four conditions of the soil : these are distinguished as (*a*) winter furrow, (*b*) summer clod, (*c*) seed bed and (*d*) summer tilth.

In the case of the first the objects are chiefly two. The soil must be inverted so as to expose a fresh layer to the action of weathering agents. Incidentally the surface so exposed should be as great as possible. Secondly the surface layer or soil proper should be left in an open condition so that rain may readily percolate through it. This permits the aeration and weathering of the upper layers and ensures the storage of the winter rain over against the needs of the next season's crop. For the production of these conditions the plough, in particular the older long-breasted type, must be regarded as a very satisfactory implement.

(*b*) The object of the summer clod condition is to kill root weeds by a process of desiccation. This is done by producing the negation of a tilth, a condition where the upper soil is in large hard clods having as little contact as may be with the subsoil. Here again the plough, properly used, is an efficient tool.

(*c*) It is in the preparation of the seed bed that our existing farm implements so often fail us. In the ordinary case what is desired is to comminute and aerate the soil, and remove root-weeds while retaining the 'frost mould' on the surface. In practice the farmer is faced with the alternative of ploughing or of relying entirely on tined implements. In the former case he buries the winter mould and brings raw clods to the surface ; in the latter he may find that he has to cross and recross his land so often that the bottom is trodden and pressed hard. What he needs is a machine that will break down clods, aerate the lower layers and drag out root weeds without inverting the soil. Above all he wants something which will do more in a single operation than anything that is now available, in order that the disadvantages of drying out and treading may be avoided. For two generations men's hopes have centred round some form of power rotary tillage, and at the moment it seems that this is at the point of practical success.

(*d*) As regards summer tilth, the preservation of a loose mulch on top of a firm fine soil has always been regarded as the essential principle. It is possible that the importance of this mulch has been exaggerated in the past, but in practice a mulch is often maintained automatically in the process of weed control. The problem of 'crusting' at the time of germination of the seed has an undoubted importance, but it seems almost impossible to devise any sure preventive.

There is one more general aspect of the tillage problem that must receive consideration. Changes in the relative costs of man power and other forms of power have made it necessary to reorganise our labour units. Our normal working group, a ploughman with a pair of slow-moving horses, is no longer economical. If we are to keep our land under cultivation we must equip and train our labourer to earn his

higher wage. We must aim at larger and faster teams and bigger implements, and we must substitute, as far as possible, the work of the horse or the tractor for that of the man.

3. Discussion on *Soil Classification.*

Mr. G. W. Robinson, Prof. J. Hendrick, Mr. L. F. Newman, Mr. C. G. T. Morison, Mr. W. Morley Davies.

4. Joint Meeting with Section L (*q.v.*) on *Educational Training for Overseas Life.*

Friday, August 6.

5. Discussion on *Agricultural Education.*

Mr. H. E. Dale, C.B., Prof. T. B. Wood, F.R.S., Mr. W. A. Stewart, Mr. J. Duncan.

6. Mr. R. G. Hatton.—*Rootstock Investigations on Apples and Plums*

7. Dr. E. J. Collins.—*The Physiological Aspect of Potato Blight.* (Taken as read.)

The physiological condition of the foliage of early, mid-season, late, and very late varieties of potatoes was determined at intervals throughout the season by making the following determinations. Leaf area was used as the basis of calculation where desirable.

1. The water content of young, medium, and old foliage.
2. The nitrogen content of the same, together with
3. The water to nitrogen ratio.
4. The diurnal variation of these data, and
5. The effect of spraying on these data.

A record of the meteorological conditions was kept.

Consistent results have been obtained over a period of six years.

The conclusion is reached that high yield and high resistance to late blight, represent the expression of the two extreme values of the same physiological complex, hence it is not anticipated that a variety combining the two characteristics will be produced. On the other hand, immunity, combined with high yield, may be obtained by the discovery of some new form or variety which possesses a definite immunity factor segregating independently of the physiological complex which, in the material at present available, determines maturation, susceptibility, and yield.

8. Exhibits at the School of Rural Economy and Institute for Research in Agricultural Economics.

Saturday, August 7.

Excursion to Reading, visiting Messrs. Sutton's seed establishment and the Agricultural Department, Reading University, and the National Institute for Research in Dairying, Shinfield.

Monday, August 9.

9. Presidential Address by Sir Daniel Hall, K.C.B., F.R.S., on *The Relation between Cultivated Area and Population,* at **Joint Meeting** with Section F (*q.v.*) to discuss *The Limits of Agricultural Expansion.* (For Address, see p. 255.)

Tuesday, August 10.

10. Prof. R. A. Berry.—*Substitution of Silage for Roots in the Feeding of Dairy Cows.*

11. Sir Arnold Theiler, K.C.M.G., Dr. H. H. Green and Dr. P. J. Du Toit.—*Minimum Mineral Requirements of Cattle.*

The experiments recorded in this paper were undertaken with the object of determining the physiological minimum requirements of cattle for phosphorus, calcium, sodium, potassium, and chlorine; main stress was laid on phosphorus and calcium. Incidentally the recent views (of Marek and others), that the *ratio* of the various minerals in the food is of dominant importance, were tested experimentally, and found to be incorrect for cattle.

The sixteen heifers used (in pairs) in the eight experiments described were kept on a basic ration extremely low in mineral constituents. To this ration different minerals were added in the various experiments.

The two animals kept on low phosphorus (about 5 gm. P_2O_5 daily) and low calcium (about 7 gm. CaO) remained stunted and developed the disease known as 'Styfsiekte' (stiff-sickness) in South Africa. The addition in another experiment of calcium to the ration (5 gm. P_2O_5, 29 gm. CaO) did not modify the adverse effect of low phosphorus, but seemed to intensify it: both animals developed 'styfsiekte,' although the mineral ratio, according to Marek, must be considered favourable. With the addition of bonemeal (100 gm. per day, bringing total P_2O_5 to 28 gm., and total CaO to 37 gm.) to the ration, the animals developed normally and, at the end of eighteen months, were in excellent condition. Bran (high in phosphorus, low in calcium) had the same effect: two animals receiving 2 lb. per day (total P_2O_5 24 gm., total CaO 8·2 gm.) showed no sign of deficiency disease in spite of the low ratio of CaO to P_2O_5.

Two animals from whose diet salt was omitted, thus receiving very little sodium (2 gm. Na_2O per day!) and chlorine (5 gm.), but whose diet was supplemented with phosphorus and calcium (100 gm. bonemeal per day) developed normally. The addition of potassium chloride to the ration of two other heifers (44 gm. K_2O as against 2 gm. Na_2O) caused no disturbance.

One of the outstanding features of the above experiments was that all animals which received sufficient phosphorus throve in spite of the practically entire absence of vitamines from their diet. Two heifers which served as vitamine controls and received a daily ration of green forage developed no better than the others. The conclusion seems justified that the vitamine requirements of cattle are negligible.

12. Discussion on *The Feeding of the Dairy Cow.*

Prof. F. B. Wood, F.R.S., Mr. R. Boutflour, Mr. W. R. Peel.

REGIONAL SURVEYS AND SCIENTIFIC SOCIETIES.

ADDRESS BY

SIR JOHN RUSSELL, F.R.S.,

PRESIDENT OF THE CONFERENCE.

It is characteristic of this country that some among its men and women of affairs have always taken an active interest in science. Elsewhere it is common enough to find the passive interest of receptive listeners prepared to hear any new thing. But here people occupied in business, professional or social pursuits, have themselves practised science: they have worked in laboratories or studied in the field, intent on doing something. In every science some of the great pioneers have been amateurs working at the subject because they loved it. Priestley is a good illustration: he expresses himself in no uncertain way as to the status of the amateur. ' The study of electricity,' he says, ' requires no great stock of particular preparatory knowledge; so that any person that is tolerably well versed in experimental philosophy may presently be upon a level with the most experienced electricians . . . several raw adventurers have made themselves as considerable, as some who have been, in other respects, the greatest philosophers. I need not tell my readers of how great weight this consideration is to induce him to provide himself with an electrical apparatus.' It was an age when the professional worker was somewhat at a discount and he remained so for many years; in none of Dickens's books, as Quiller Couch reminds us, is the professional man anything more than an incompetent bungler lacking common sense and sometimes also common honesty.

With the exhaustion of the surface workings of science more systematic investigations became necessary. The amateur with a few shillings' worth of apparatus was no longer able ' to make himself as considerable ' as people with long specialised training, working in well-equipped laboratories. He still survived, but in the degenerate form depicted in Charles Keene's ' Uncle Fusby ' in the early days of ' Punch '; his societies lasted into our own time. I remember as a child being taken to one of their meetings in a provincial town where the mysteries of ' galvanism ' were being displayed by a gentleman who also discoursed on geology, biology, astronomy and other sciences: ' The Infinitely Great and The Infinitely Little,' to borrow a phrase of the period. But this is all past; the type goes on for ever, but it now studies more occult subjects far transcending the bounds of physical and biological science.

The amateur who is prepared to take trouble still has his place, however, in the advancement of knowledge. In the observational sciences—botany,

geology, anthropology, archæology—he has been able not only to interest himself but to help others.

To-day I wish to discuss a subject of growing importance in which the amateur worker can find full scope for his activities and his wide outlook. Pioneer workers have shown the great interest and value of regional surveys and the advantage of arranging a network of surveys over the whole country. Like other scientific work, it is team work, but such as can be and is being done by the societies represented here to-day: usually it is best done in consultation with the professional workers of the University Schools of Geography.

England has been surveyed many times and from many different points of view. The first travellers to record their results—Antoninus, who detailed the Roman routes, the Domesday surveyors and others, give only the lifeless record, absolutely indispensable to the historian, but of little direct interest to others; even in this age of reprints, when the most obscure authors of antiquity are resuscitated by some enterprising editor and publisher, these volumes remain peacefully buried. The first accounts that tell us what the place looked like, what people did or how they adjusted themselves to their environment, still maintain their interest. Camden's 'Britannia' (1586 and later), Leland's 'Itinerary,' even Drayton's 'Polyolbion,' held a high place, as may be judged by their prices in spite of the number of times they have been reprinted; while Giraldus Cambrensis is probably more widely read now than ever during the 740 years that have elapsed since his wonderful propagandist journey through Wales for the great Crusades.

A regional survey is a survey of a district as an environment for human beings—an account of its physical features, its natural characteristics, its flora, fauna, &c., culminating in a study of the ways in which they affect human life and activity. It is this human aspect that gives the non-professional worker his opportunity, for his close touch with human affairs enables him to appreciate and to express the human standpoint. The specialist in science may be misunderstood; indeed, he often is like the musicians in the 'Blue Bird.'[1]

A regional survey must be based on the specialised work of the Geological Survey and, in the few cases where they have been made, the various Natural History surveys made by professional specialists having the time, the resources, and the necessary detachment. The regional surveyor need not attempt the task of combining the results of all these specialised surveys into one prodigious comprehensive whole; anyone who did so would deserve and would probably meet the usual fate of the encyclopædist. For special purposes the separate surveys have been assembled as in Arctic and Antarctic regions, and the biological survey of Clare Island off the coast of Mayo, one of the biggest things of its kind; but the fact that Clare Island has an area of only 4,000 acres, while its survey, though only sectional, fills three great volumes, warns us what a terrible task a completely comprehensive survey of the country would be. It is unnecessary to labour the

[1] *Mytyl*: 'What are those people doing who are making such a noise?'
Tyltyl: 'They're the musicians.'
Mytyl: 'Are they angry?'
Tyltyl: 'No, but it's hard work.'

definition; many of the geographers in charge of the University Schools of Geography have in hand regional surveys which show better than any description what they are. One can mention only a few: Prof. Fleure of Aberystwyth, Prof. L. P. Abercrombie of Liverpool, G. L. Pepler of the Ministry of Health, W. S. Lewis of Exeter, C. B. Fawcett of Leeds, Prof. Roxby and Miss Winchester of Liverpool, Dr. Rudmore Brown of Sheffield, Messrs. Barker and Fitzgerald of Manchester, W. W. Jervis of Bristol, Mrs. Ormsby of the London School of Economics, Harold Peake, John Jones and others are actually doing the work. Fortunately, also, several surveys have been published which serve as models of what societies can do. The South-Eastern Union of Scientific Societies, following up the pioneering work of the Croydon Natural History Society, have published no less than seven surveys, the two latest being of Folkestone and Essex. Under the enthusiastic guidance of Messrs. C. C. Fagg and G. E. Hutchings one may hope for more.[2] Miss McLean at the Wyggeston School and Mr. G. T. MacKay at Reigate have shown what schools can do.

Surveys fell into two groups: those dealing with the areas in or near towns studied finally in relation to town planning, of which some admirable examples have been published; Prof. Abercrombie's Sheffield and East Kent; Adams and Thompson's West Middlesex and Thames Valley; and the town planning surveys of Manchester, Doncaster, Deeside and others. Fortunately the importance of this work is now recognised. I shall deal only with surveys in country districts.

The best beginning is to construct a model of the region, as this shows, in a way no map can do, the features of chief importance in the survey. The records have to be carried on to maps; the 6-in. makes a good basis for records, but the 1-in. is often best for displaying the results. The topographical details of the Ordnance Survey maps[3] are correlated with the data given by the Geological Survey maps and supplemented with the fuller explanations of the Memoirs. The hills and the valleys have not come by chance; reasons for their formation should be clearly set out in the regional survey in a way that people without geological training can easily follow. Of the climatic data, the ten-year average rainfall should be mapped and the annual rainfall studied to ascertain the degree and nature of the variability. Temperature data are less easy to utilise; but the observations on vegetation—the so-called phenological observations—help in their interpretation. Perhaps the two chief factors are lateness and liability to late frosts; these affect the native vegetation, the farmer and the gardener, and they may profoundly affect the utilisation of the land.

The second part of the survey is to show how this natural material has influenced and has been influenced and utilised by mankind. The region is mapped out into four main divisions: inhabited land (houses and their gardens); arable land, including fruit and market gardens; permanent grass land; and uncultivated land, including woodland,

[2] See the excellent record of work done, 'Report of Regional Survey Section,' *Trans. S.E.U.S.S.*, 1925-6.

[3] The Ordnance Survey Department makes special arrangements for supplying scientific societies with maps for purposes of survey work.

commons, heaths, bogs, &c. These main divisions should be clearly distinguished on the map so that they stand out above all subdivisions. In villages, with which alone I am dealing, three common divisions are the village street, the farms, and the park or mansion. Commonly the village street is very ancient, being at a ford or the beginning of a heath or in some part of the road where the mediæval traveller would wish to spend the night without going farther, or it grew up round some sacred spot, or on a slight elevation surrounding wet ground, like the numerous leys in the Eastern Counties, Holbeach and other places in Lincs, or where water could easily be obtained, as illustrated in the villages below the chalk escarpment. In general there was a definite reason why the village street grew up where it did, and that reason should appear from the survey.

The position of the farmhouses is determined partly by physical and partly by human factors. Water supply was always a dominating necessity, also shelter from wind and storm; accessibility was probably less important. But there was the human element as well. The Celtic settlements of the west are scattered over the land, this being the convenient arrangement for cattlemen using grass or natural herbage for their animals; while the Saxon settlements of arable farmers in the east and south tend for technical reasons to be more compact, the farmhouses being near the village; in Hertfordshire the outlying farms are called 'Ends,' *e.g.* Hammond's End, Mackery End, &c.

The park or mansion, if it is old, commonly grew out of the manor house, and its position frequently has some relation to hunting; it may be near or in a warren or near wooded glades where deer could be hunted; usually the park land cannot be cultivated easily if at all, so that it was not enclosed in mediæval times.[4]

The permanent grassland falls into three groups: first-class land with great capacity to carry live stock, some being of such value for fatting that it would never be laid in for hay; second-class land so useful to the farmer that he spends money on manures, cultivation, and the maintenance of hedges and fences; and third-class land used for rough grazing which receives little manure or other attention. The divisions are necessarily conventional, but a reasonable basis is the number of animals the land will carry or fatten per acre. I suggest the following:—

First Class.—Land fattening without additional cake one bullock per $1\frac{1}{2}$ acres, or six sheep.

Second Class.—Land on which some cake or corn is commonly needed, carrying one bullock or six sheep per $1\frac{1}{2}$ acres, but not usually finishing them for the butcher without some supply of cake or corn.

Third Class.—Land suitable only for breeding purposes or for young animals growing into 'stores.'

The grazing characteristics of the land should be recorded; its healthiness; any diseases to which animals are specially liable; whether

[4] It is a common fallacy to suppose that parks absorb land that might be producing food. I have had occasion to survey a number of them, including Richmond, Hampton Court, Chartley, and many others, but have rarely found any important area of land suitable for cultivation or for anything more than the grazing for which it is at present used. There are often possibilities for improving the grass, but not to any sensational extent.

grazing is restricted to summer or winter; whether the land is suitable for breeding; whether it is commonly used for all animals. In the South-Eastern Counties grassland on the chalk and on the sand is healthy; though it will not easily fatten animals it is suitable for breeding purposes and particularly for sheep. But there is the important technical difference, which has many consequences, that the chalk grass is suitable for summer grazing, while the sandy soil grass is suitable only for winter grazing. Marsh land presents a third case; it is suitable only for summer grazing, and it generally fattens animals. It is wet, however, and encourages certain parasites, liver flukes, and the organisms causing foot rot. These distinctions have far-reaching effects which, however, come more appropriately into an agricultural than into a regional survey.

The best method of subdividing the arable land is according to the length and character of its rotation. The commonest rotation has four courses: two of corn, one of roots or green crops, and one of rotation grass or clover as shown by the following statistics for England and Wales (1915-1924):—

Total area of arable land	11.5 million acres
Total corn	5.7 (=50%)
Total roots and other green crops . .	3.4 (=29%)
Rotation grass and clover . . .	2.4 (=21%)

But the rotation is modified in many places. In the fertile parts of Lincolnshire, especially the Holland Division, it is shortened to three courses, the roots being mainly potatoes; in the chalk districts it is often lengthened to five courses by putting in an additional corn crop, or to six or more courses, two of which are green crops fed to sheep on the land. In the north and west the period in grass is lengthened. The records should show what the corn crops are and whether they are sown in winter or in spring, and the map should show the chief crops. Oats are commonly grown all over the country, occupying about half of the total corn land: we produce about 85 per cent. of what the nation consumes. The fact that an area is marked as arable land almost implies that one of its corn crops is oats; their absence would certainly need recording on the map. Wheat and barley are more symptomatic. Wheat is in such severe competition with the great continental plains of Canada, the United States, Australia, South America, and Eastern Europe, that it survives only in particularly favourable conditions. It is sown in late autumn, and therefore is not grown in the north where the winters are too severe or in the north-west where they are too wet; it needs a steady supply of moisture at its roots, and therefore is grown on heavy soils or on such of the lighter soils as are well supplied with moisture. It does not ripen well in wet weather, and therefore is grown only where the summer rainfall is normally low. All these conditions are connoted by the presence of wheat as an important crop. Barley, on the other hand, is usually spring sown; it is therefore unaffected by the winter weather and is found in the coldest parts of the country. It is commonly found on the lighter soils and it tolerates shallower soil conditions. There are advantages about wheat and barley that induce farmers to grow them; if they cannot do so successfully they grow oats in both breaks.

Of the main root crops, swedes and turnips are the commonest, and are

associated with meat production; mangolds are associated with dairy production; and potatoes with conditions specially favourable for plant growth and marketing.

The rotation grasses generally remain only one year, but in special conditions they remain two or more, particularly where the summer and autumn are sufficiently moist to permit of growth. The deviations from the one year ley should be noted.

Orchard and market garden land is so important that it should be separately mapped, and the records should show the crops, the markets, and the relation to transport. For example, a great industry in growing tomatoes and cucumbers under glass has developed in the Lea Valley north-east of London, the determining factors being (1) the accident that the industry was started there about sixty years ago by the first Joseph Rochford; (2) the proximity to London and direct accessibility to Manchester and the northern towns; (3) the abundance of water in the subsoil so near the surface that it can be cheaply pumped out of shallow and inexpensive wells.

The great out-door fruit and market garden industry of the Evesham district is determined by (1) the relatively mild winters and equable climate; (2) the undulations of the land surface causing great varieties of aspect; (3) the open soil lying on a heavier soil; (4) good railway communications.

If the conditions are suitable the industry once started tends to develop, because new entrants trained by those already there tend to settle in the same district, rather than risk failure in an entirely new district.

The weed flora is important. It persists long after it has become established, and may throw light on the earlier history of the land. Economically also a weed survey is valuable.

The uncultivated land should be subdivided on the map according as it is wet or dry, open or wooded. The distinctions thus become: open dry heath or down, frequently in these days used as golf courses; marsh or bog; dry woodland, mainly fir, pine, birch, beech, Spanish chestnut; moist woodland, mainly oak, hornbeam, ash. Further subdivision is the province of ecology, and the Ecological Society should be consulted if the area of waste is of great size.

A system of symbols has been devised by the Regional Survey Committee of the Geographical Association, distinguishing sharply between these four great divisions of inhabited, arable, permanent grass and uncultivated land, and making the necessary subdivisions.

The symbols can be made more expressive by using the initial letter of the crop to denote the normal rotation. The crops actually growing at the time of the survey need not be shown on the map as they change each year, and in any one field may be determined by some accidental factor. The important thing is to show all the rotation land and the types of the rotation. This can be done by the Geographical Association symbols.

It is obviously a great task to go over a whole region to find out whether its rotation is four or five course and what are its chief crops. There are two ways in which the labour can be lightened. The farmer works his rotations by fields rather than by precise areas. A rough estimate of the

crops and the rotation can be obtained by counting the fields on the roadside under each crop and working out the proportion of the whole under each crop. Precise figures are in the possession of the Ministry of Agriculture, and may be obtained in the form of parish returns by scientific societies or students properly introduced by a University School of Geography.[5] The returns show, however, only the data for the parish, and parish boundaries are not necessarily fixed by physical conditions.

The crop information is not complete without a record of the breeds of animals and of their movements. The interpretation would generally need an agricultural expert.

This completes the material of the survey but not the survey itself. The important task remains to discover how and why the present position arose. The manner of utilising land is determined by two factors; the physical and meteorological conditions determine which out of all known crops can be grown, and the economic conditions determine which of all possible crops actually are grown. The economic conditions have the further effect of determining the standard of life and activity of the people, and therefore the general character of the village, its buildings, and other human productions. It is difficult, if not impossible, to assess economic conditions adequately, but the standard for comparison can usually be obtained from some of the official inquiries and edicts made from time to time. So far as the agricultural labourer is concerned, his minimum wages are in each county prescribed by the Agricultural Wages Board and published. There is no secret about the minimum, but the actual is greater and not usually known. The official minimum is probably comparable with the figures published in past years by the various Government committees and commissions appointed to inquire into the state of agriculture in the United Kingdom, *e.g.* 1902, 1906, 1907, 1913, 1919, &c. It is far more difficult to arrive at any opinion as to the farmer's economic condition at any time; indeed, he rarely knows it himself. Fortunately for purposes of the regional survey, it is unnecessary to descend to details, only a general impression is needed.

It must not be supposed that the countryman ever elaborately studied the various possibilities of crop production and land utilisation, and then deliberately selected those best adapted to the conditions of the time. For the regulations of their own affairs human beings do not adopt the principles of science or the deductions of pure logic; they proceed by the method of trial and error, testing all things even if they often fail to hold fast to that which is good. In the trial and error method, the important thing is to have the record; to know what was tried, what was the result, and whether in the end the result sufficiently accorded with human needs to survive.

Fortunately many of the records exist and the process can be traced pretty completely. Mediæval men had to produce most of what they

[5] The Ministry of Agriculture informs me that this information is supplied free of charge to Universities, Research Institutes, &c., requiring it for purposes likely to be of educational value. Students are charged the cost of extraction and tabulation if the work occupies a clerk for a whole day or more. On an average particulars of ten to fifteen parishes can be extracted, tabulated and checked for about 11*s*. Certain regulations are imposed in accordance with the Act under which the returns are obtained.

wanted or go without. They were much more closely governed by the natural conditions than we are; their houses were made of local material —which they became adept at working up—their food was determined by regional characteristics; economic factors as we know them to-day hardly came in. They always wished for, but could not always obtain, good crops of wheat, barley, oats, peas or beans, and grass. Wheat is the most fastidious in its requirements and cannot be grown successfully all over these islands. Oats and rye will grow in colder, wetter conditions, and will tolerate sour soils. They were therefore commonly grown in the west and the north. The old system practised in these islands for nearly a thousand years was a three-course rotation: bread corn—wheat in the east and south, oats or rye in the north and west; drink corn—barley—or pulse; then the land was left in weeds or grass. The arable land was in three large fields divided into strips.

Three great improvements gradually came in and were well marked by the end of the eighteenth century. Addition of marl to land which had previously grown only rye enabled it to carry wheat instead[6]; the marl added enough calcium carbonate to overcome the sourness and sufficient clay to give other necessary properties. All over the country, therefore, marl pits were opened and land was marled in the hope of obtaining the desired wheat. The names 'Marl pit lane,' 'Marl pit field,' 'Ryelands,' and 'Wheatlands' often survive.

The second great improvement was the enclosure and division of the arable fields, the commons, and the wastes. While the land was left open no great improvement was possible, for there was no inducement for anyone to do anything. Many survivals of the open fields can still be found in field names. We have 'Harpenden field' on our own farm, while near us the traces of Pickford Common and Manland Common still persist. A further improvement consisted in the introduction of new crops into the rotations which raised the output of the land by 50 to 100 per cent.

Four sources of information are available:—

1. The surveys of the individual counties by the first Board of Agriculture set up in 1793 under the presidency of Sir John Sinclair. They were printed in 1794-96 in quarto volumes with very wide margins to allow of manuscript notes; from these a fuller edition was issued in octavo volumes about 1804 to 1812; they practically all contained maps, which, however, have been removed from many of the second-hand copies now on the market. These surveys are by far the best made up to that time.

The corresponding account of Scotland, issued in 1791-99, is called the Statistical Account.

These surveys form the basis of the numerous descriptions and accounts of the countryside written in the early part of the nineteenth century.

2. About the middle of the nineteenth century the Royal Agricultural Society of England and the Highland Agricultural Society of Scotland published in their journals accounts of the agriculture of the various counties. So far as they go these are good; they are less full than the older surveys, but they carry the story on to its next stage, for the period was one of great technical achievement.

[6] *E.g.* Basil Quayle, 'General View of the Agriculture of the Isle of Man, 1794,' and many other surveys published about then.

3. Since 1816 there have been numerous Government bodies, including Royal Commissions, inquiring into the state of agriculture, and although of all forms of literature a Commission's Minutes of Evidence is the most tedious, nevertheless the information is of great value and importance for the survey.

The Geographical Association is now publishing in its *Journal* bibliographies of the various counties. It is also endeavouring to aid those who are making surveys by putting them in touch with sources of information; its library has been enriched by a generous grant from the Carnegie Trust.

4. In our own time there is unfortunately no systematic survey comparable with those of the first Board of Agriculture. Agricultural teaching and research both suffer in consequence. In 1911 Sir Daniel Hall and myself published a survey of Kent, Surrey and Sussex on lines which we believe to be suitable for an agricultural region. The Oxford Institute for Research in Agricultural Economics under Mr. C. S. Orwin has been responsible for careful surveys of Oxfordshire and Berkshire; short accounts have also been published by G. W. Robinson of the soils of Shropshire and North Wales. For each county there are now agricultural organisers and advisers who have a considerable amount of information and should be consulted in any regional survey of a rural area.

All these records are general; they may not help in the details of the region under investigation, though they give the broad outlines without which the details may be meaningless. For the detailed history of the region great efforts should be made to get at the old estate or parish maps. Other records usually exist in the village accessible to all. Field names often go back for centuries, recording the original owner or some ancient usage. The size and boundaries of the parish afford a measure of its resources in the past. The non-puritanical character of the average Englishman led him in bygone days to build beautiful churches which tell something of the life of the people of old. The oolite ridge running from the Cotswolds across into Lincolnshire is rich in churches and added chapels of the fifteenth century, when the wool trade brought much money to the sheep farmers.

Later on the builder's craft was applied to house making. The farmhouses show the standard of prosperity and of comfort in the days when they were built and something of the vicissitudes of later times. The abundance of fine old Jacobean houses speak of the great wealth of that period. In some of the less accessible parts of the west and south, these houses have remained almost unchanged; the Jacobean period represented the climax of prosperity. But elsewhere the houses were greatly altered in the eighteenth century or after the Napoleonic wars or in the 'sixties of the last century, indicating further peaks of prosperity when people had enough money to pull their houses to pieces and modernise them. The position of old ecclesiastical buildings may show close relationships to agricultural resources.

The value of a regional survey is great. Its importance to the general community for town planning has been abundantly demonstrated by Professor Abercrombie and Mr. Pepler. For students it provides a valuable record of the countryside as it is now, as its resources are used

now, and how these things came to be. It provides the teacher with material of unparaleled educational value and of absorbing interest to the child. But perhaps its greatest value is that it arouses an interest in the countryside, which we should hope will be followed by a desire to keep the best of what we have. For the countryside of England is rich beyond all others in human and artistic interest. The long procession of Briton, Roman, Saxon, Dane, and Norman has passed through our land, unbroken and unhasting, on some of the very roads we still use, living in some of the places where we live. Some of the generations have added much to the countryside before they left it: the great roads made by the Romans; the clearing of the forest by the Saxons who founded many of our villages and towns; the wonderful churches of the Normans and those who followed for the next 400 years; the beautiful houses and cottages of Jacobean times; the mansions and gardens of the eighteenth century; many of these have come down to our own day tended by the men who held them for a while and then passed them on to us.

And what are we doing with them? Happily for the most part looking after them well. The churches in particular are cherished and safeguarded against the terrible churchwarden restorations that did so much damage in the nineteenth century. Other important buildings, listed by the Historical Commission, though not absolutely safe from neglect or destruction, are at any rate looked after by someone. But many beautiful relics of the days of the craftsmen, wonders in wood and iron and stone, are not and perhaps cannot be fully protected, yet if once lost they cannot be replaced. And unfortunately the civic conscience is not always alert to look after these things. It is one of the difficulties of democracy that the generations of voters are so short and there is scarcely time to educate them. A curious apathy seems to come over those who live with these wonderful works. We need only recall the trouble about the beautiful old hospital at Croydon, the destruction of fine old cottages at Stourbridge to make a new library, at Craven Arms, at Storrington on the South Downs, at Box in Wiltshire,[7] and the astonishing piece of vandalism begun but happily not completely perpetrated, and, let us hope, not to be repeated, in taking down the fine old fifteenth-century house at Lavenham to build it up somewhere else. It is difficult to believe that descendants of the great craftsmen who built that wonderful Suffolk town have no appreciation of its beauty. Once these things have gone they have passed for ever. Fortunately the Council of the Royal Society of Arts is interesting itself in the matter, and let us hope, in conjunction with the National Trust and the Society for the Protection of Ancient Buildings, will be able to do something. The sympathetic attitude of the Office of Works is well known.

It is not only our fine old specimens of handicraft that are in danger. The rapid spreading out of the towns into the country is leading to the erection of houses in all sorts of places, worst of all in long narrow streaks along the omnibus routes.[8] Some people make two houses, one for the

[7] *The Times*, July 6, 1926.

[8] For some account of the harm being done in the countryside, see L. P. Abercrombie, 'Preservation of Rural England,' Hodder & Stoughton.

week-end and one for the middle of the week. At present anyone may build anywhere where land can be bought, and usually anything so it be of good brick or stone and conforming to the local by-laws about the drains. Our children are being brought up with a noble ideal :—

> ' I will not cease from mental fight
> Nor shall my sword sleep in my hand
> Till we have built Jerusalem
> In England's green and pleasant land.'

But it is an ill notion of the new Jerusalem to set up a lot of incongruous bungalows and little villas with asbestos-tiled roofs, devoid of any trace of craftsmanship, and scattered over the countryside regardless of their effect on the landscape.

The educated middle classes, however, know better, and they are building houses of artistic value, unobtrusive and fitting in well with their surroundings, and happily their example is infectious; some of the cottages recently put up by the local authorities in the villages are very attractive and will improve with age. Fortunately, man cannot permanently destroy Nature's beauty, and the blots we now deplore will always be within the power of our descendants to remedy. What we would most desire would be to enjoy our heritage ourselves and to hand it on undimmed, and if possible enhanced, to those who come after us.

The Conference of Delegates of Corresponding Societies met at Oxford on Thursday, August 5, at 2.15 p.m. The delegates present were 61 in number, representing 64 societies.

The President of the Conference, Sir John Russell, F.R.S., delivered an address on the subject of Regional Surveys, which is printed in full above.

Prof. H. J. Fleure (Cambrian Archæological Association) moved, and Sir George Fordham (Hertfordshire Natural History Society) seconded, a cordial vote of thanks to the President; and in discussion there spoke also Prof. J. E. Duerden (South African Association), Dr. Edgar Salman (Cardiff N.H. Society), Sir David Prain, F.R.S. (Gilbert White Fellowship), Dr. R. Cockburn Millar (Edinburgh N.H. Society).

The Report of the Committee on Kent's Cavern was presented by Prof. J. L. Myres (General Secretary), and the reappointment of the Committee was moved by Dr. G. A. Bather (John Evelyn Society), and seconded by Mr. G. A. Garfitt (representing the Anthropological Section). The Report is included in the Report of the Oxford Meeting of the Association.

Mrs. Forbes Julian (Torquay N.H. Society) read notes on some of the Kent's Cavern specimens.

Dr. E. Greenly (Geological Society) and Mr. S. W. Wooldridge (Geologists' Association) gave notice of a motion respecting temporarily exposed geological sections.

The reappointment of the Corresponding Societies Committee was announced, consisting of the President of the Association (*Chairman ex-officio*), Mr. T. Sheppard (*Vice-Chairman*), the General Secretaries, the General Treasurer, Dr. F. A. Bather, Sir Richard Gregory, Sir David

Prain, Sir John Russell, Mr. Mark L. Sykes, Dr. C. Tierney; with authority to co-opt representatives of Scientific Societies in the locality of the Annual Meeting. The conference adjourned to Tuesday, August 10, at 2 p.m.

At the adjourned meeting the motion for the reappointment of the Kent's Cavern Committee was confirmed.

It was resolved to submit to the Committee of Recommendations :—

That steps be taken, with the co-operation of local societies, to make systematic records of temporarily open geological sections, well-borings, and the like.

The resolution was discussed by Dr. E. Greenly (Geological Society), Mr. S. W. Wooldridge (Geologists' Association), Dr. G. A. Bather (John Evelyn Society), Mr. T. Sheppard (Yorkshire Naturalists' Union), Mr. A. W. Oke (Southampton Rambling Club), Prof. J. L. Myres (General Secretary), Mr. C. C. Fagg (Croydon N.H. and Sci. Society), Mr. F. S. Dymond (Hastings and St. Leonards N.H. Society), Mr. P. Matthews (Letchworth and District Naturalists' Society), Dr. R. Cockburn Millar (Edinburgh N.H. Society), and Prof. J. E. Duerden (South African Association). Delegates were asked to bring the resolution before their respective societies, and to emphasise the importance of prompt photographic record, prompt report to the Ordnance Survey and the Geological Survey, and the co-operation of persons habitually traversing the district under observation, such as postmen and other local officials.

It was resolved to submit to the Committee of Recommendations :—

That the Council be asked to represent to His Majesty's Government the serious detriment to scientific investigation and to the dissemination of scientific knowledge which results from the present restrictions on the importation into this country of cinematograph films recording scientific observations intended for purposes of education and advanced study and not for commercial purposes, and to ask for their amendment.

It was announced that similar resolutions were being submitted by the Zoological and Anthropological Sections.

Dr. R. Cockburn Millar urged the enrolment of both local and metropolitan societies in the list of the Conference of Delegates.

A hearty vote of thanks was passed to Sir John Russell for presiding over the Conference.

REFERENCES TO PUBLICATIONS OF COMMUNICATIONS TO THE SECTIONS

AND OTHER REFERENCES SUPPLIED BY AUTHORS.

Under each Section, the index-numbers correspond with those of the papers in the sectional programmes (pp. 337-431).

References indicated by 'cf.' are to appropriate works quoted by the authors of papers, not to the papers themselves.

General reference may be made to the issues of *Nature* (weekly) during and subsequent to the meeting, in which summaries of the work of the Sections are furnished.

Section A.

1. Cf. W. L. Bragg, C. G. Darwin, and R. W. James, 'The Intensity of Reflexion of X-rays by Crystals,' *Phil. Mag.* **1** (May 1926); W. L. Bragg and J. West, 'The Structure of Beryl, $Be_3Al_2Si_6O_{18}$,' *Proc. Roy. Soc.* A, **3** (1926).

2. Cf. *Proc. Roy. Soc.* A, **106**, pp. 441, 463, 709 (1924); **107**, pp. 157, 636 (1925); **109**, pp. 476, 584 (1925); **112**, pp. 214, 230 (1926); also expected further publications *ibid.* and in *Phil. Mag.*

4. Expected to appear in *Phil. Mag.*

6. Expected to appear in *Phil. Trans. Roy. Soc.*

8a. Cf. 'Modern Theories of Integration,' *Math. Gaz.*, **13**, p. 72 (1926); 'The Lebesgue-Stieltjes Integral,' *Proc. Cambridge Phil. Soc.*, **22**, p. 935 (1925).

8d. Cf. 'Hankel Transforms,' *Proc. Cambridge Phil. Soc.*, **21**, p. 463 (1923); 'A Contribution to the Theory of Fourier Transforms,' *Proc. London Math. Soc.*, ser. 2, **23**, p. 279 (1923).

8e. *Math. Gaz.*

11. 'Om en ny Metode til Frembringelse af Lydsvingninger' (On a new Method for the Production of Sound Vibrations): *Det kgl. danske Vidensk. Selsk. math.-fys. Medd.*, **1**, p. 13 (1919); 'On a new Method for the Generation of Sound-waves,' *Phys. Review*, **20**, p. 719 (1922); 'New Investigation on the Air Jet Generator for Acoustic Waves,' *Det kgl. danske Vidensk. Selsk. math.-fys. Medd.*, **7**, p. 6 (1926).

15. *Proc. Cambridge Phil. Soc.*, **23**, pt. 4.

16a. *Phil. Mag.*

16b. Cf. Abel's article in Crella (1826), 'Ueber die Integration der Differential Formel,' &c., *Phil. Trans.*, Dec. 1903 stereoscopic figures in *Phil. Trans.*, 1896.

18. Cf. *Science*, Apr. 30, 1926, p. 433.

19. Expected to appear in *Proc. London Math. Soc.*; cf. 'Ueber die Bedeutung der Jensenschen Formel für einige Fragen der Komplexen Funktionentheorie,' *Acta Universitatis Szeged*, **1**, p. 81 (1923).

20. *Sitzungsb. math.-phys. Klasse d. Bayrischen Akad. d. Wissensch.* (1927).

21. 'Variazioni e fluttuazioni del numero di individui in specie animali conviventi,' *Mem. R. Accad. dei Lincei* (1926).

22. *Zeitsch. f. Physik*, **38**, p. 803 (1926).

23. *Engineering*, Aug. 27, 1926.

24. Expected to appear in *Proc. Roy. Soc.* A.

25. Cf. two lectures before McGill Phys. Soc., published as pamphlet by Mercury Press, Montreal.

26. Cf. King, 'Specific Gravity of Wool . . .', *Brit. Research Assoc. for Woollen and Worsted Industries, Publ.* no. 19 (1923); Hirst, 'The Swelling of Wool Fibres,' *do.*, nos. 17 (1922), 31 (1924); Hirst and King, 'Kemp,' *Journ. Textile Inst.* (1926),

p. 264 ; Hirst, 'Some Theoretical and Practical Observations on Milling,' *B.R.A. publ.*, no. 9 (1920) ; King and Barrett, 'The Sulphur Content of Wool,' *Journ. Textile Inst.* (1926) ; Hirst, in *Textile Recorder* (May 1924), p. 81 ; Barker and Hirst, 'Colour Problems in the Woollen and Worsted Industries,' *Proc. Optical Conv.* (1926). Paper submitted for publication to Phys. Soc. London.

29. Probably to appear in *Math. Gaz.* Cf. 'On the Foundations of Combinatory Analysis Situs, I and II,' *Proc. Roy. Acad. Sci. Amsterdam*, **29**, pp. 611. 627 (1926) ; 'On the Superposition of n-dimensional manifolds,' *Journ. Math. Soc. London*, **1**, p. 162 (1926).

30. Cf. *Proc. Math. Soc. London*, ser. 2, **21**, pt. 6, p. 420.

Section B.

3. Cf. *Journ. Chem. Soc.*, **129** (1926), as follows : Charlton, Haworth, and Peat, 'A Revision of the Structural Formula of Glucose,' p. 89 ; Haworth and Westgarth, 'Derivatives of γ-Xylose,' p. 880 ; Cooper, Haworth, and Peat, 'The Constitution of the Disaccharides. Pt. X. Maltose,' p. 876 ; Haworth and Hirst, 'The Structure of Fructose, γ-Fructose, and Sucrose,' p. 1858 ; Haworth and Nicholson, 'The Structure of Lactones from Simple Sugars,' p. 1889 ; Drew and Haworth, 'A Critical Study of Ring Structure in the Sugar Group,' p. 2303.

3a. *Journ. Chem. Soc.*

6. Cf. *Rec. Tran. Chim. Pays-Bas* as follows : 'Sur une nouvelle méthode de dosage du soufre dans les composés organiques et dans quelques produits techniques : le pétrole, la houille, le gaz d'éclairage et le caoutchouc' (1922), p. 112 ; 'Le dosage de l'oxygène dans les composés organiques' (1922), p. 509 ; 'Le dosage de l'azote dans les composés organiques par hydrogénation catalytique' (1924), p. 643 ; 'Le dosage de l'oxygène dans les composés organiques (deuxième communication)' (1924), p. 899 ; 'Le dosage de l'azote dans la houille, le coke et les matières albuminoïdes' (1925), p. 271 ; 'Le dosage de l'arsenic dans les composés organiques' (1926), p. 364 ; 'Le dosage mercure à l'état métallique dans les composés organiques et inorganiques,' *ibid.* ; Meulen et J. Heslinga, 'Nouvelles méthodes de dosage du chlore, du brome et de l'iode dans les composés organiques. I. Méthode par hydrogénation' (1923), p. 1093. Appendix, Thorpe and Whiteley, *Students' Manual of Organic Chemical Analysis* (1926).

Section C.

4. Cf. *Bull. Geol. Soc. Amer.*, **37**, 1, p. 157 (Mar. 1926).

5. Cf. 'Ursus Anglicus, a new species of British Bear,' *Ann. Mag. Nat. Hist.*, ser. 9, **11**, p. 490 ; 'Intercostal Blood-vessels in Mesozoic Crocodiles,' *Proc. Geol. Assoc.*, **35**, p. 263.

9. Expected to appear in *Zeitsch. f. Vulkanologie.*

13. Cf. (in part), 'The Structural Evolution of the London Basin,' *Proc. Geol. Assoc.*, **37**, pt. 2 (1926).

16. Expected to be presented to Geol. Soc.

21. To appear in *Geol. Mag.*

Section D.

1. *Nature*, Aug. 21, 1926, etc.

3. Cf. *Trans. Entom. Soc. London*, 1919.

4. *Ann. Nat. Hist.*, Nov. 1926.

6. Cf. 'On the Phylogeny of the Pierniæ,' *Trans. Entom. Soc. London* (1894), for diaposematism ; 'On the Relation of Mimetic Characters to the Original Form,' *ibid.* (1896) ; 'Mimetic Attraction,' *ibid.* (1897) ; Address to Section D, *Report Brit. Assoc.*, 1919.

10. Cf. Gunther, *Early Science in Oxford*, 3, pp. 280-530 (1925) ; 'Musæum Tradescantianum,' *Old Ashmolean Reprints* I (1925) ; *The Times*, Oct. 30 (1925).

11. Expected to appear in *Q.J.Micro. Sci.* Cf. 'On the reproductive processes of the Brandling Worm, *Eisenia Fœtida*,' *ibid.* 80, p. 559.

12. Cf. 'On the Ground Plan of Wing-pattern in Nymphalids and certain other families of the Rhopalocerous Lepidoptera,' *Proc. Zool. Soc. London*, 1924, p. 509; 'On a remarkable Dislocation of the Components of the Wing-pattern in the Satyrid genus Pierella,' *Entomologist*, **58**, p. 266 (1925); 'On the Modes of Evolution of the Wing-pattern in Nymphalids and certain other Families of the Rhopalocerous Lepidoptera,' *Proc. Zool. Soc. London*, 1926, p. 493.

13. Cf., in *Trans. Entom. Soc. London*:—'The life history of *Pseudacræa eurytus hobleyi*' (Feb. 11, 1913), p. 706; '*Pseudacræa eurytus hobleyi*, Neave: its forms and its models on Bugalla Island, L. Victoria' (March 31, 1914), p. 606; '*Pseudacræa eurytus hobleyi*, its forms and its models on the islands of L. Victoria, and the bearing of the facts on the explanation of mimicry by natural selection' (July 26, 1920), p. 84; '*Pseudacræa eurytus* and its models in Eastern Uganda' (April 15, 1924), p. 469; also a note on the last in *Proc. Entom. Soc.* (1925), p. xiii.

17. *Trans. Roy. Soc. Edin.*, **54**, pt. 3 and future vols.

19. *East Africa*. 3, No. 105, p. 4 (Sept. 23, 1926), No. 107, p. 54 (Oct. 7, 1926). Cf., in 'Progress Report on Investigations into the Bionomics of *Glossina palpalis*,' Part xii, *Reports of Sleeping Sickness Commission, Roy. Soc.* (1912), p. 79; 'Second Report on the Bionomics of *Glossina fuscipes* (*palpalis*) of Uganda,' Part xiv (1913), *ibid.*; 'Third, fourth, and fifth Reports on the Bionomics of *Glossina palpalis* on L. Victoria,' Part xvii (1919), *ibid.*; 'Report on a test of a method of attacking *Glossina* by artificial breeding places,' *Bull. Entom. Research*, **13**, Part 4, p. 443 (April 1923); 'Report on an investigation into the epidemiology of Sleeping Sickness in Central Kavirondo, Kenya Colony,' *ibid.*, **15**, Part 2, p. 187 (Nov. 1924); 'Biology of Sleeping Sickness,' *Kenya Medical Journ.* (1925, May, June, July), **2**, Nos. 2, 3, 4.

22. Substance to appear in *Proc. Zool. Soc.* and *Brit. Journ. Exper. Biol.*

24. 'Report on the Lethal Action of Lead Salts on Fishes,' pubd. for private circulation as serial No. 190, Report No. 129, by Standing Ctee. on Rivers Pollution, Min. of Agriculture and Fisheries. Cf. 'On the fauna of rivers polluted by lead-mining,' *Ann. Appl. Biol.*, **11**, 1 (1924); 'On the biological factors involved in the destruction of river fisheries by pollution due to lead-mining,' *ibid.*, **12**, 1 (1925); 'The lead-mine as an active agent in river-pollution,' *ibid.*, **13**, 3 (1926); 'Faunistic ecology of Cardiganshire trout-streams,' to be published in *Journ. of Ecology* (spring, 1927).

25. Expected to appear in *Brit. Journ. Exper. Biol.*

Section E.

2. Cf. 'Saxton's Map of England and Wales,' *Geog. Journ.*, Jan. 1926; 'La Cartographie des Routes de France au XVIIIe Siècle,' *Bull. Soc. Géog.* 1925 (Paris, 1926); 'Un Carte-Routière de la France,' *La Géographie* (1926); 'Les Guides Routiers, Itinéraires et Cartes-Routières de l'Europe, 1500-1850'; *Bull. Soc. Archéol. Hist. et Art. Le Vieux Papier* (Lille, 1926); *Notes on the Itineraries, Road-books and Road-maps of France*, privately printed, Southampton, 1926 (v. *Report Brit. Assoc.* 1925, p. 325).

6. Cf. *Illustrated London News*, Aug. 14, 1926, p. 292; a further paper to appear in *Archéologie*. **8.** To appear in *Geog. Journ.*

10. Expected to appear in *Geog. Journ.* Cf. 'The Map of Ireland A.D. 1300-1700,' Belfast Nat. Hist. and Phil. Soc., *Proc.* session 1923-24; 'Rathlin Island in the Portolan Charts,' Roy. Soc. Antiq. Ireland, *Journ.*, **55**, Part 1 (June 30, 1925); 'The Study and Classification of Mediæval Mappæ Mundi,' Soc. Antiq. London., *Archælogia*, **75**; 'Mediæval Maps,' Manchester Geog. Soc., *Journ.*, **39-60** (1923-24); 'The Boundary between Scotland and England in the Portolan Charts,' Soc. Antiq. Scotland, *Proc.*, **12**, fifth series, session 1925-26; 'Scotland in the Portolan Charts,' *Scottish Geog. Mag.*, **42**, nos. 3, 4, 5 (May, June, September, 1926).

11. Cf. 'Oceanography of the Peruvian Littoral,' *Geog. Review*, **13**, p. 64 (1923); 'Recent Oceanic Phenomena along the Coast of South America,' *Monthly Weather Review*, Vol. **53**, pp. 116, 117 (1925); 'Oceanic and Climatic Phenomena along the West Coast of South America during 1925,' *Geog. Review*, **16**, p. 26 (1926); Murphy, *Bird Islands of Peru* (Putnam's, New York and London, 1925).

17. *Modern Science* (expected). **18.** *Journ. Manchester Geog. Soc.*, autumn, 1926.

SECTION F.

2. *Contemporary Review*, Oct. 1926. **8.** *Economic Journ.*, Dec. 1926.

9. To form final chapter of book on coal industry expected to appear 1927. Cf. Bowie, *Sharing Profits with Employees* (Pitmans, 1923) ; 'The British Coal Agreement,' *Journ. Pol. Econ.*, Univ. of Chicago (April and August, 1924).

SECTION G.

2. *Engineering.*

5a. *Electrician*, Aug. 13, 1926.

5b. *Electrician*, Aug. 13, 1926, and other journals. Volume on Electro-farming in press. Cf. papers, *Roy. Dutch Inst. Engin.*, 1921 ; *Inst. Elec. Eng.*, 1922 ; *Farmers' Club*, 1922 ; *S. Wales Inst. Eng.*, 1923 ; *World Power Conf.*, *B.E.Exhib.*, 1924 ; *Internat. Conf. on large Electric Systems*, 1925 ; *Inst. Elec. Eng.*, 1926 ; *World Power Conf.*, Basle, 1926 ; *First British Electro-farming Conf.*, Chester, 1925.

7. *Engineering*, Aug. 20, 1926.

8. *Engineering*, Aug. 27, 1926.

10. *Engineering*, Aug. 10, 1926. Cf. previous B.A. papers, in *Engineering*, Oct. 3, 1924, and Sept. 16, 1921.

11. *Rep. Internat. Cong. App. Math. and Mech.*, Zurich, 1926.

12. *Engineering*, Sept. 24, 1926.

13. *Engineering*, Aug. 13, 1926.

15. *Electrician* and *Engineering*, Aug. 13, 1926.

16. *Engineering*, Sept. 17, 1926.

17. *Engineering.* **18.** *Cassier's Industrial Management.*

Engineering should be referred to for further reports of the transactions of this Section.

SECTION H.

1. Cf. 'Committee on Vital Statistics of Primitive Races,' *Proc. Austral. Assoc. Adv. Sci.*, **17**, p. 113 (1924) ; 'On Method, Approach, and Diagnostic Fallacies in dealing with the Problem of Depopulation in the Pacific,' *ibid.*, p. 475.

4. To be published in *Man.* **9.** *Antiq. Journ.*, Jan.–Mar. 1927.

10. Cf. *The Assyrian Herbal*, Luzac, 1924 ; 'Assyrian Medical Texts,' *Proc. Roy. Soc. Medic.*, passim ; *On the Chemistry of the Assyrians*, Luzac, 1925. *Cambridge Ancient History*, Chap. iii ; further matter to appear in *Harmsworth World History.*

11. Cf. *Excavations at Kish*, I. Paris, 1924, and vol. 2 to follow. Cf. also Mackay, *Report on the Excavations of the ' A ' Cemetery at Kish*, Chicago, 1925.

13. *Antiquaries' Journ.*

16. Cf. *Illus. London News*, Aug. 14, 1926 (illustration by A. Forestier).

20. Cf. 'Rural Settlements in S.W. Wales,' *Geog. Teacher*, spring 1926. Probably to appear in *Eugenics Review.*

23. Cf. *Proc. Prehist. Soc. E. Anglia*, **5**, pt. 1, p. 35 (1926).

24. To appear in *Journ. Roy. Anthrop. Inst.* Cf. *ibid.*, **55**, p. 146 (1925).

29. To appear in *Journ. Roy. Anthrop. Inst.*

31. To appear in *Rep. Internat. Americanist Congress*, 1926 (in French). Cf. *Note on the Ancient Mexican Calendar System*, Internat. Cong. Amer. (privately printed, Dresden), 1894 ; *The Fundamental Principles of Old and New World Civilisations*, Peabody Museum, Harvard Univ., 1901 ; 'The Periodical Adjustments of the ancient Mexican Calendar,' *Amer. Anthropol.*, 1904 ; *The Astronomical Methods of the Ancient Mexicans*, Boas Memorial Vol. (New York, 1906).

34. To appear in *Folk-Lore.*

Section I.

1. Cf. 'The Reality of Nerve-Energy,' *Proc. Roy. Soc. Canada* (1919); letters in *Nature*, Sept. 9 and Nov. 18, 1922; paper to appear in *Scientia* (Milan); further paper to be sent to *Scientific Monthly* (New York).

4. Cf. *The Physiology of Vision* (Bell & Sons, 1920); 'Trichromic Vision and Anomalous Trichromation,' *Proc. Roy. Soc.* (1913); 'The Physiological Aspect in Science,' *Medical World* (Apr. 23, 1926).

12. Cf. Industrial Fatigue Research Board, *Reports*, 35, 39; *Special Report Series*, no. 100.

17. *Proc. Roy. Soc.* B, **100,** p. 251 (1926).

Section J.

1. Expected to be published by Brit. Psych. Soc.

6. *Brit. Journ. Psychol.* **17,** pt. 2 (Oct. 1926).

9. Published as a *League of Nations Union* pamphlet.

11. To appear in *Journ. Nat. Inst. Indust. Psychol.* Cf. 'Psychology of Advertising,' *ibid.*, **2,** no. 8, p. 377; 'The Emotional Appeal of Advertising,' *ibid.*, **3,** no. 2, p. 304.

12. *Journ. Nat. Inst. Indust. Psychol.*, Oct. 1926.

14. Cf. Lloyd Morgan, *Life, Mind, and Spirit,* pp. 309 *seq.*; further reference expected in forthcoming publication provisionally entitled *An Organic Theory of Nature.*

15. *Mind,* Oct. 1926. Cf. *Psychology of Reasoning,* and *Biological Memory* (Kegan Paul).

16. *Journ. Nat. Inst. Indust. Psychol.*, Oct. 1926.

19. Cf. *The Nature of Personality* (University of London Press).

20. Probably to appear in *Brit. Journ. Psychol.* Cf. *ibid.*, **16,** pt. 2 (Oct. 1925).

23. Expected to appear in *Modern Science.*

Section K.

4. Results to appear probably in part in *Mycologia,* and in part in *Illinois Biol. Monographs.*

6. *Journ. Genetics,* **17** (Aug. 1926).

7. Expected to appear in *Sci. Proc. Roy. Dublin Soc.*, and in *Notes from the Botanical School of Trinity College, Dublin.*

8. Expected to appear in *Trans. Roy. Soc. Edin.* Cf. *Report Brit. Assoc.*, 1923, p. 488.

10a. Gunther, 'The Herbal of Apuleius Barbarus,' for Roxburghe Club, 1926.

11. Probably to appear in *Journ. Genet.*; cf. *ibid.*, **5,** 3 (Mar. 1916).

12. Probably to appear in extended form in *Journ. Genetics* in 1927.

19. Expected to appear in *Journ. Ecology.* Cf. 'Algæ of Stanklin Pool, Worc.,' *Proc. B'ham N.H. & Phil. Soc.* (1912); 'Heleoplankton of North Worcestershire,' *Jour. Linn. Soc.* (1916); 'Heleoplankton of Berkshire,' *ibid.* (1922); 'Phytoplankton of Shropshire and Cheshire,' *ibid.* (1925); 'Phytoplankton of Isle of Anglesey,' *ibid.* (1926); 'Phytoplankton of Hornsea Mere, E. Yorks,' *Naturalist* (1924); 'Phytoplankton of the Wicken Fen Area,' in *Natural History of Wicken Fen,* Part II (April 1925); 'Ryton Willows Pool' (in col. R. B. Cooke), *Trans. N.H. Soc. Northumb., Durham and Newcastle-on-Tyne* (1924); 'Phytoplankton of Freshwater, etc.', *Journ. Ecology* (1923).

21. To appear in *Hartley Botanical Publications,* Liverpool Univ.

23. Forwarded to *Annals of Botany.*

26. Cf. Kräusel and Weyland, 'Beiträge zur Kentniss der Devonflora II,' *Abhandl. Senckenberg. Naturf. Ges.*, **40**, H.2; Kräusel, 'Aus der Verseit der Pflanzenwelt,' *Senckenb. N. G. Bericht*, **56**, H.9 (1926).

26a. Expected to appear in either *Ann. Bot.* or *Journ. Applied Biol.*

28. Further paper expected to appear in *Ann. Bot.* Cf. W. W. Garner and H. A. Allard, 'Effect of Length of Day and other Factors of the Environment on Growth and Reproduction in Plants,' *Journ. Agric. Research*, **18**, p. 553 (1920); 'Effect of Light on Plants,' p. 569, *Annual Rep. Smithsonian Inst.*, Washington (1920); 'Flowering and Fruiting of Plants controlled by Length of Day,' Separate 852 from *Year Book of U.S. Dept. of Agriculture*, 1920 (Washington Govt. Printing Office, 1921); 'Further Studies in Photoperiodism. The Response of the Plant to Relative Length of Day and Night,' *Journ. Agric. Research*, **23**, no. 11, p. 871 (1923); W. W. Garner, H. A. Allard, and C. W. Bacon, 'Photoperiodism in Relation to Hydrogen-ion Concentration of the Cell-sap and the Carbohydrate Content of the Plant,' *ibid.*, **27**, no. 3, p. 119 (1924); Garner and Allard, 'Localization of the Response in Plants to Relative Length of Day and Night,' *ibid.*, **31**, no. 6, p. 555 (1925); M. A. H. Tincker, 'Effect of Length of Day on Flowering and Growth,' *Nature*, **114**, p. 350 (Sept. 6, 1924); 'The Effect of Length of Day upon the Growth and Reproduction of some Economic Plants,' *Ann. Bot.*, **39**, no. clvi (Oct. 1925).

29. To appear in detail in *Guide-book to Irish Tertiary Fossil Plants* (Brit. Mus.).

SUB-SECTION K* (FORESTRY).

4. To appear more fully as *Oxford Forestry Memoir*, no. 6.

6. *Timber Trades Journal*, Aug. 21, 1926.

7. Cf. 'The Swamp Cypresses, *Glyptostrobus* of China and *Taxodium* of America, with notes on allied Genera,' *Proc. Roy. Irish Acad.*, **36**, section B, p. 90 (May 1926).

9. *Engineering*, Sept. 17, 1926.

10. *Estates Magazine*, Sept. 1926.

12. To appear in *Q. Journ. Forestry*.

15. *Trans. Roy. Scot. Arbor. Soc.*, **40**, pt. 2 (1926). Cf. J. Brunchorst, 'Ueber eine neue, verheerende Krankheit der Schwarzfhore.' *Bergens Museums Aarsberetning 1887*, n. vi (1888); I. Jorstad, *Norske Skogsykdommer*, p. 49; Frank Schwarz, *Die Erkrankung der Kiefern durch Cenangium abietis, Beitrag zur Geschichte einer Pilzepidemic*, Jena, 1895; James R. Weir, 'Note on Cenangium abietis (Pers) Rehm on Pinus ponderosa Laws,' *Phytopathology*, **2**, no. 4, p. 166 (April 1921).

16. Expected to appear in *Q. Journ. Forestry*, Jan. 1927.

17. *Trans. Roy. Scot. Arbor. Soc.* Cf. Dallimore and Bruce Jackson, *A Handbook of Coniferæ* (Edward Arnold); Dallimore, *The Pruning of Trees and Shrubs* (Dulau).

18. *Timber Trades Journal*, Aug. 21, 1926.

19. *Timber Trades Journal*, Aug. 14, 1926. *Engineering*, Sept. 17, 1926.

20. To be published as 'Moisture Movement through Wood: the Steady State,' *Technical Note no.* 2, *Forest Products Research Lab.* Cf. 'Moisture Movement in Wood: The Transfer of Moisture between two Discs,' *Ann. Applied Bot.*, **13**, p. 37 (1926).

22. To appear in *New Phytologist* (1927).

SECTION L.

2. Cf. *Natural History of the Oxford District* (handbook issued in connexion with Oxford Meeting, Oxford University Press), pp. 328-336; 'The Evans Collection in Oxford,' *The Times*, Aug. 3, 1926; R. T. Gunther, *Historic Instruments for the Advancement of Science* (1925).

SECTION M.

1. *Economic Journ.*, Sept. 1926.

6. *Journ. Pomology and Hort. Sci.*, **6**, no. 1 (Dec. 1926). Cf. 'Apple Rootstocks, their particular Suitabilities for different Soils, Varieties, and Purposes,' *Ann. Rep.*, East Malling Research Station, 1926.

EDUCATIONAL TRAINING FOR OVERSEAS LIFE.

Report of Discussion at a Joint Meeting between Sections L (Education) and M (Agriculture). Ordered by the General Committee to be printed in extenso.

Sir Thomas Holland, F.R.S., who presided, opened the proceedings with the observation that the discussion had been arranged mainly to consider the results of an inquiry made by a committee appointed by the Association in 1923. The committee, under the chairmanship of Dr. Gray, had published two reports, based on answers to a series of questions issued to some 500 heads of secondary schools, supplemented by information obtained from education authorities. The committee started with the accepted theorem that the congested state of the professions in Great Britain and the opportunities that existed in the Dominions for the right sort of young men and women offered opportunity for development in education. They concluded that the bias given to the curriculum at school very often determined a boy's choice of a career, and they had obtained evidence to show that opportunities for practical work on the land, supplemented by manual training, did not necessarily interfere with ordinary school work. On the contrary, it was found that boys became more self-reliant, more observant, and developed in character in ways which improved their interest in school work. If it be true that field work on school farms was in itself of educational value, apart altogether from its influence in selecting a neglected vocation, it was well to discuss methods for removing the difficulty, which now prevented a more general adoption of field and farm education. The subject was one in which, as they realised from the Presidential Address, His Royal Highness the President was deeply interested, and no member of the Association had had the same opportunities for ascertaining the way in which the Empire could be developed by migration of the right sort of boys and girls from the congested to the sparsely populated areas. Lord Balfour called attention to the fact that two previous meetings addressed by non-specialists in Science were followed quickly by epoch-marking advances in Science, and he predicted something of the sort as the outcome of that meeting. The remarkable address given the previous night foreshadowed two such developments—the organisation and the correlation of research activities by the super-councils which had been set up in each of the Dominions ; and this would have its effect indirectly on migration : it would affect, in the first instance, university students, and through them the secondary school boys. At the Imperial College most of the qualified graduates in biology were booked for scientific work in the Colonies. Graduates from the Dominions were also coming to us for

post-graduate training and research. The movement among university students must be followed by a similar tendency among the schoolboys, as knowledge extended of the geography of the Empire. The report of the committee dealt mainly with the question of creating an interest in agriculture, but in the Dominions engineers were wanted just as much, and boys who were inspired with a liking for the engineering industry as boys would find opportunities in the Dominions for college training of as high an order as could be given to them here. Those who knew the Dominions realised that influence on their boys and girls was far more important than influence in this direction on their men. The Dominions did not want men who were merely failures here. Their opportunities were far better if they went out to the Dominions as boys. When, as the committee hoped, boys and girls were inspired with a real desire to see the Dominions and enjoy the life there, rather than wait until they had failed to make good in this country, that movement would be for the good of the Empire as a whole.

Sir Alfred Yarrow: I have paid many visits to Canada, passing from east to west, and am fairly well acquainted with what is going on in those parts. I have taken advantage of such trips to study the prospects of young men who emigrate to Canada—and what applies to Canada will apply to many of the Dominions. I refer to young men who intend to emigrate in order to earn a livelihood and make positions for themselves.

In Canada there are many natural advantages, such as unlimited timber, mineral wealth, virgin soil suitable for growing wheat or fruit; large rivers and streams that can be turned to account by means of hydro-electric plants to produce current cheaply.

There can be little doubt that there are greater opportunities for young men abroad than in the Old Country; and I refer only to those young men who are willing to work, and work hard.

I have found many well-educated young men, full of energy, fail through the lack of a few hints which are needed to guide them when going abroad.

What is wanted first is a good British public school education. Many young men go abroad straight from an English university. Now the point is, if a lad has determined to emigrate, and intends to take a university course, he should go to a university in the country where he intends to settle. He can, however, take a course at an English university and then follow it up by a post-graduate course abroad. He thus becomes acquainted with the new conditions of life, makes friends with his fellow-students who were born and bred in the country, and these friendships no doubt add to his happiness and are useful to him in after-life. On the other hand, if he goes abroad straight from an English university and expects to get employment at once, he cannot secure a position so easily as a lad who has been through a university in the country where he has settled. The fact is, many employers make a point of going to the local universities or schools to select the young men whom they need, and they are guided in their selection by the reports of the teachers; while a lad going straight from an English school or university is unknown.

Introductions to refined families on the spot are most important, and social accomplishments are not to be despised. A knowledge of music,

for example, gives a young man a welcome into refined society which those who have not that knowledge would not obtain.

The first thing a lad should do when he goes abroad is to take part in games. He should join an athletic club, and anyone coming from a British public school or university would have no difficulty in joining such clubs.

One would naturally select to follow an industry which is most likely to develop rapidly, and the principal of a university or public school will be in a position to give good advice as to what line of work might be best to follow. In Canada, for example, paper-making from wood pulp, hydro-electric engineering and agriculture are on the increase.

The invariable custom of students in Canada is to make practical use of their holidays; many get employment in industries such as mining, surveying, engineering, and thus obtain practical knowledge of great value. They get paid for their services, and what they receive, together with what they may be allowed from their homes, will probably be ample to cover the cost of living.

There is no doubt that in our schools in the Old Country there is great need for a more practical type of education. I contend that a lad who has had workshop experience, is accustomed to use his hands as well as his head, is more likely to gain a good position than those who have been brought up to sit on office stools and do secretarial work, of whom there are many more than are needed; and this is due to the fact that an altogether undue importance is placed in this country on a black coat. There is an unlimited number of lads who qualify for banks and insurance offices, but the majority of boys would find a far wider field open for practical work abroad.

What is needed in every young man to be successful is character combined with knowledge. He must have self-control, must be abstemious in all things, and, although his companions may laugh at him at times, he must have courage to withstand their mockery, and when the time comes for some important post to be filled, he will be the one most likely to be chosen.

It is the character in the Anglo-Saxon race from which we have sprung that has made this little island, scarcely known to the ancients, the leader of the world during the last century; and those young men who go abroad should always have this fact in view and maintain the high standard of honour which they have inherited.

A lad well brought up and coming from good stock must never forget the traditions of a British gentleman wherever he may go.

The Hon. W. Ormsby-Gore, M.P., said that he entirely agreed with Sir Alfred Yarrow. If they considered the question of the training of people in this country who meant to make their lives either in the Dominions or the Colonies, character was a factor that must never be lost sight of. The important thing to maintain in education was not what was merely to be put into the mind, but the tradition and spirit of English education, and undoubtedly that in the past had been bound up in the ancient universities and public schools with education in the Humanities.

But apart from this, it would seem that for overseas, in addition to

this education in the Humanities, definite scientific training was desirable. He considered it most important to bring both British and Dominion farmers to realise more than they did to-day the value of the teaching of science as applied to agriculture.

He was glad to notice that special efforts were being made in regard to emigration in connection with the public schools. There was a definite New Zealand scheme for emigration for public school boys; further than that they were now having two very important developments, viz. the interchange of teachers between the Dominions and this country, and also the first organised Empire tour of boys of different public schools.

He also called attention to the great importance of geographical teaching, which could be of immense value in educating the mind, the growing mind particularly. He did not mean geography which merely dealt with place names, topography, but real geography, economic geography—man in relation to his environment. He considered there was a great need both here and in the Dominions for extending the knowledge of the economic and historical geography of the Empire.

There was one further point which should not be forgotten—namely, the inevitable contrast between life in the young new Dominions and the life in this country as we knew it to-day. That contrast particularly applied to the educated mind, and particularly to the educated women of this country who were going out. He had also heard it said by people of the Dominions in speaking of agriculture that they would rather take a town lad from England between the ages of sixteen and eighteen, provided they got him before he was spoiled, than take a man who had been in agricultural surroundings in this country all his life, because it was easier to train quite raw material than to unlearn the habits of those who had become ingrained from youth up. That was why all proposals to train for any length of time those who were going to the Dominions overseas in practical agricultural work in this country had to be examined very carefully.

Any attempt to deal with the needs of our own people in this country, by the inclusion in our public schools and universities of a special course for intending emigrants, was not an easy problem. To the fact that educated people were wanted oversea he could testify. He knew from the Dominions and from the point of view of the Colonial Office the difficulty of getting trained men for education, agriculture, and for research work. He earnestly hoped that steps would be taken to increase the interest in scientific research, particularly in regard to agriculture.

Sir Daniel Hall said he would confine his remarks to agriculture alone, and agriculture was a matter of prime importance to the Empire. As he should have occasion to lay before the Association later on, we were likely to get short of food in no very distant future, and therefore the development of the food resources of the Empire was of importance if we were to keep ourselves. With regard to this great question of agriculture and the employment therein overseas of young men from this country, there was not the slightest doubt that the young Englishman had not a good character in the Dominions. That arose from various reasons: first of all, in certain countries they were accustomed to the boy who had been sent there for his country's good, and he, of course, did

not create a favourable impression. Even the really good type of boy earned rather a bad reputation because of his un-handiness in doing any of the one hundred odd jobs that occurred in up-country life, and therefore was regarded as rather a fool. Why was this ? It arose because most of our boys and girls were brought up in a very complicated organisation that led them not to do things for themselves, but confronted them everywhere with orders 'to keep off the grass.' They did not fend for themselves ; and in every stage of life had things done for them. Our whole scheme of education, whether in our high or elementary schools, was so designed to train the mind that it overlooked the importance of handiness. Training for agriculture itself, as Mr. Ormsby-Gore had already pointed out, was different here. Our technique here was very different from the technique overseas ; it was a very advanced technique, involving a more elaborate form of cultivation which was not wanted in the simplified crop-growing systems of our overseas Dominions. The final training should be given in the country itself. His advice was to send the boy for a year to one of the agricultural colleges in England and give him a scientific grounding, which he would get better there than anywhere else. Then let him go on a farm for a summer to learn to handle horses and stock, and then let him finish his college course in the chosen Dominion. That would be his best introduction to the agricultural life of the new country. It did not follow that in order to secure this handiness the young intending emigrant should go through the elaborate training of an agricultural labourer, but it was essential that he should obtain a short practical course which would teach him how to handle a horse, take it out of its stable and harness it in a reasonably workmanlike way, as well as to hitch it in a wagon and drive it out of the yard without bumping into a post. Knowledge of such matters, as well as the knowledge of how to handle stock, round up a herd of cattle and move them along, and things of that kind, would make all the difference between a boy whom the Colonial farmer wanted and one who would be regarded as a fool. He ought also to have a little knowledge of tools, rough woodwork, be able to make a gate or put up a fence, and to do estate carpentry of that kind. Given some fundamental scientific education, together with that handiness to which he had referred, there was an abundance of young men and boys in England for whom could be found a useful and prosperous career in our Dominions and in our Colonies.

Miss Gladys Pott said she was going to plead with those who were responsible for putting overseas educational settlement problems before the authorities in this country, to consider the importance of emigration of the sexes in equal numbers, a point which the report in 1917 of the Dominions Society had strongly emphasised. It was a great mistake that there had never been proper equalisation of the sexes in settlements overseas, a condition which was essential to the character of the Empire.

Schemes for emigration of public school boys lost much of their value without the necessary complement of girls of the same class. She would appeal to educationalists to formulate some scheme to attract young women overseas, especially in view of the surplus female population in the Home Country, where even well-educated girls were drifting into

blind-alley occupations, who abroad in a wider field would develop splendidly.

She would remind the meeting of the recommendation of the Royal Commission to the British Government that there should be special training for women to go overseas. She quoted Cecil Rhodes on South Africa—'It is British women I want to see'—and asked how British homes were going to be built up without British women.

Members of the Headmistresses' Association had assured her that if there were training schemes for women, young girls would be far more ready to go. The kind of training that was wanted was such as would fit the women for being good wives, mothers and keepers of the house. Homes in this country would also benefit from such schools.

She did not consider it necessary to start special institutions for the purpose, but did ask that in the consideration of overseas settlements the importance of encouraging women as well as men should be remembered.

Sir John Russell, F.R.S., said the Committee which reported to them that day had set out to find some solution of the problem how to turn our boys and girls into useful citizens of the overseas Dominions. The Committee began by inquiring into the most suitable training for those boys and girls whose instincts were for the country and to whom the wide spaces of the Empire appealed. Obviously the training should develop habits of observation and give the background of general knowledge that would enable them to get into the ways of the new country as easily as possible and to derive the fullest value from the life they would lead there. England, as we all knew, was a country for sane educational experiments, and it was soon found that certain schools had not only successfully visualised the general problem but had made much progress with working out the practical details. The basis was the school garden, round which much of the school work centred. There had been in recent years a surprising development of these gardens, and they had been brought more and more into prominence in the school curriculum. They were used not merely for technical instruction in the arts of gardening, but for the much wider purpose of training the intelligence of the child and developing powers of seeing and doing things for himself; they were in the best schools becoming a highly effective educational apparatus.

Those of them who had to do with the farmers of England knew how alert and intelligent the present generation of men were. It was wholly wrong to describe them as being unable or unwilling to learn. There was a greater demand from farmers for lectures, demonstrations and other forms of instruction than ever before. Twenty-five years ago it was often difficult to obtain an audience or to arouse much interest or discussion. It was not that the farmers lacked intelligence, but they had little faith in education as it was then practised in many schools.

To-day it is no uncommon experience for a lecturer to find that the largest hall in the town has been taken; that it is filled with farmers, many of them young men, and that the lecture is heard with intelligent appreciation and well discussed afterwards. An important modern movement is on foot, especially in Wiltshire, Devon, Warwickshire and other counties, in the shape of Agricultural Discussion Societies which are attended

by enthusiastic bodies of young farmers. This keenness on the part of young farmers for education is very impressive; much of it is due to the county agricultural organisers, but it became possible only because of the good work of the country school teacher, who, with the sympathetic help of the inspectors, has been struggling to give the country child a love of the country and a knowledge of the things in the countryside.

The Committee felt that this type of work could usefully be extended to other schools so as to turn out boys and girls fitted for life in the Empire. Discussions with teachers, however, brought out the difficulties felt by those who had not hitherto made much use of the school garden. The chief trouble in schools other than elementary schools was the overloaded syllabus; teachers pleaded that they were bound to prepare most of their children for certain examinations, and any extended use of the school garden would be possible only for special classes or courses for children that might proceed overseas. Whether one wanted it or not, the special course always tended to become the duffers' course, and it would be fatal if the idea got abroad that only the duffers from our schools were trained for overseas. One thing which impressed the visitor to Canada or other parts of the Empire was that the overseas Dominions were prepared to welcome boys and girls from this country, but only on the condition that they represented our good material and not our failures. The Committee therefore set aside the suggestion there should be special classes at school for boys and girls who wished to go overseas. That being so, the solution seemed to lie with the University Examining Boards, which determined the type of question set at the important school examinations. Those teachers who had tried the experiment of using the school garden, and giving a rural bias to their work, knew that the subject was as well adapted for mental discipline and for orderly systematic development as any other. Therefore the Committee was examining the possibility of inducing the University Examining Boards to modify the syllabus, without in any way detracting from the standard, so as to include tests that would show whether these children had been adequately educated. If more schools could take the matter up they could give to those children who loved the country and the wide open spaces the necessary bias and background, and equip them to take full advantage of the special training that would come later, and would in any case best be given in that country to which the child was going.

Mr. T. S. Dymond said that the Overseas Training Committee were very anxious that there should be some concrete outcome of that meeting, and had drafted a resolution which, from the speeches which had been delivered that afternoon, he believed would be accepted unanimously.

> 'That, with a view to the promotion of Imperial interests overseas and the unlimited opportunities of land settlement, the Council be requested to draw public attention to the demands of the Dominions for the settlement of young people of good education, and to urge that adequate preparation for overseas life should be given in schools.'

A suggestion having been made from a lady at the back of the hall that the resolution be amended to include 'young people of both sexes,' the chairman said he thought that that was already included in the term

'young people of good education,' but it might be worth while making it quite definite.

Mr. Dymond said he would accept the amendment, and the resolution, amended accordingly, was then put and carried, the chairman intimating that the resolution would be conveyed to the Council.

Mr. G. W. Olive said it was good to feel that the meeting would attract much public attention to the urgent need for bringing more and more of the boys and girls of the Homeland into the wide and yet close family bond of the Empire. The Mother Country and the Dominions formed one organic whole, and as various members of the one body they were interdependent and must function as one. The general public had not hitherto understood that the needs of the Dominions and the opportunities they presented together constituted such an important question, and one so vital to our national and Imperial welfare, that it should loom very large and receive the full attention it deserved when the education of elder children was being considered. Many thinking people were in complete accord with the opinion of the Committee on Educational Training for Overseas Life that in schools we adopt the narrow rather than the wide view.

The preparation of boys for life on the land had been an important part of his work for over twelve years, and in this time it had been possible to see some of the results. What he principally saw was: Old boys who were engaged in life on the land were, in the main, big men—not only in body, but big in mind, in ideas. How schools could ever have regarded them as human material of such insignificant potential value that adequate preparation for their future careers was quite beyond the province of the school, seemed inconceivable. But that was exactly the position now. He had a large number of old boys abroad, fellows who had proved themselves real sterling quality, doing good work for their Dominions and themselves, as farmers, ranchers, managers, organisers, and scientific experts. These were living witnesses to the value of educational training for life overseas.

He had a special word to say on behalf of the type of boy whose ability and mental capacity were demonstrated at their best when they found expression in action, in doing, and in creating things. The Empire needed this type, quite as much as the type which excels with pen and paper in the examination room. To his mind it was a dangerous practice to attempt to satisfy the needs of the outdoor type of boy by preparing him along the rigid lines of some examination syllabus, for unless great care was taken the procedure might have a deadening influence on the very activity it was intended to stimulate and promote. It was not difficult to arrange suitable schemes of work, but each school should prepare its own scheme, adapted to its own special facilities. The essential point was that it must be real and practical. The scheme should not only prepare the boy, but also test him as far as possible. By testing, he meant that it should be ascertained whether the boy had the liking, ability, and physical capacity that would be required of him for an overseas life. A boy who could not get up in the morning, or one who would shirk rather than work, would be of no use in the Dominions. On the other hand, some boys had a real love for life on the land, were handy

with machinery and implements, and seemed to have a natural gift in managing animals. Such boys go abroad and prosper, whereas the former return disappointed men or become wasters.

A real difficulty was the question of capital. The parents of an only son would usually not allow him to go abroad, though they had the capital. Where there were three or four boys, the parents favoured the idea of life overseas for one at least, but often their capital was a sheer impossibility where money had to be shared among a number of boys who have already cost a good deal to educate.

Mr. H. W. Cousins said he could well imagine the audience agreeing that the idea might be excellent for the large public and private schools, but very dubious concerning its application in the case of small rural grammar and secondary schools. Yet was it not to these smaller schools in country areas to which they must look for the greater proportion of those who would eventually emigrate and settle overseas ? What chance had such schools, with their limited staffs, of giving to their pupils any training in rural subjects that would prepare them for agricultural life overseas ?

His reply to that was—and he was privileged to say so as the result of seventeen years' experience as headmaster of rural secondary schools—that such work could be done, indeed was being done to-day, in several small rural secondary schools without in any way prejudicing the value of the curriculum for those pupils destined for the Universities or any of the usual professions.

To base one's teaching largely upon the environment of the child—upon the plants and animals and daily tasks of farm and garden—naturally meant that biological studies entered largely into the curriculum, and his contention was that biological teaching in schools was not only practicable but also essential if they were to give the best possible training for life to every boy and girl whatever his (or her) future work might be, whether in town or country.

Further, one of the reasons why he advocated biological studies in school was because children were interested in living things—in plants and animals—and this natural interest was a wonderful incentive to work. He knew there were many who said, 'Let the boy come up against hard things ; it will do him good to learn to overcome difficulties.' Was it not true in the majority of our State-aided schools to-day that, while there were many children whose parents were worth their thousands, there were also many others who had to be given free places, maintenance grants, and travelling expenses in order that they might receive a secondary education ? Were not many of those children up against hard things from the day of their birth ? Was there much virtue in finding difficult things for them in school ?

For such children he wanted school to be a place they would enter with joy, a place which should teach them that education could lift them out of the hard places of life and give them pleasure and content ; to do this he must get interest into the work and no subject was more fruitful than biological studies as a source of interest.

He would also say in this connection that too often in the past the curricula of their schools had been too academic in character, and had not

given a fair chance to the fellow who was good at doing things rather than in writing or talking about them. It was impossible for boys to preserve their self-respect if they were continually being reminded by the school curriculum that they were hopelessly inferior people. A school that existed merely to convince a boy how stupid he was, was not doing its job. Only a tiny fraction of boys were not good at something or other, and the school curriculum must be wide enough to give every fellow his chance. A boy might be hopeless in the art room, but a real artist in making up a seed bed ; poor indeed in the mathematical master's eyes, but an expert in the manufacture of simple surveying instruments.

In conclusion, he asked for the inclusion of biological and practical studies in the curriculum not only from the point of view of overseas settlement, for, after all, it was only a small percentage of their boys and girls who would go abroad, but because they were essential factors of a good general education.

He believed, indeed, that if the Overseas Committee of the British Association would only take up this question of rural education for its own sake, apart from any consideration of settlement overseas or of farming at home, it would do more than anything that had been done for many long years to regenerate rural England, and to place the economic, social, and spiritual life of England on a higher plane than it had ever reached before.

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References to addresses, reports, and papers printed in extended form are given in italics.

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